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APPENDIX E

DISSOLVED AIR FLOTATION

COSTS FOR DISSOLVED AIR FLOTATION FACILITIES

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PART OF CITY AND COUNTY OF SAN FRANCISCO'S
MASTER PLAN STUDY FOR WET WEATHER CONTROL PROGRAM

JULY 1971

ENGINEERING-SCIENCE, INC.
RESEARCH AND DEVELOPMENT LABORATORY
600 Bancroft Way Berkeley, California 94710
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DISSOLVED AIR FLOTATION

APPENDIX E

COSTS FOR DISSOLVED AIR FLOTATION FACILITIES

Part of City and County of San Francisco's
Master Plan Study for Wet Weather Control Program

submitted by

City and County of San Francisco, California

prepared by

Engineering-Science, Inc.
Research and Development Laboratory/Berkeley

for

Environmental Protection Agency
Water Quality Office

July 1971

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FOREWORD

This volume constitutes the fifth of seven technical appendices to the Project Report on Treatment of Combined Sewer Overflows by the Dissolved Air Flotation Process. Appendices in this series are:

A. Phase I - Pre-Construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach

B. Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility

C. Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process - A Pilot Plant Study

D. Design Factors for Baker Street Dissolved Air Flotation Facility

E. Costs for Dissolved Air Flotation Facilities

F. Characterization of the Receiving Water and Beach Intertidal Zone Environment

G. Performance Evaluation of Baker Street Facility with Raw Sewage

Appendix E is submitted in fulfillment of DPW Order No. 86,585 between the City and County of San Francisco and Engineering-Science, Inc.

This report, prepared in limited edition for utilization in City and County of San Francisco's Master Plan study for wet-weather control, is under review for approval by the Environmental Protection Agency, Water Quality Office.

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CHAPTER I

INTRODUCTION

The majority of sewers in the City of San Francisco carry both sanitary sewage and storm water runoff. The three major existing treatment facilities operated by the City have been designed to process the dry-weather sanitary flow, but during those periods when the combined flows exceed plant capacity, the excess quantities are bypassed and not treated in the plants. One promising method of treatment for these high volume flows is the dissolved air flotation treatment process.

To better assess the applicability of the dissolved air flotation process to the City's existing major treatment plants and to those areas not now being served by treatment facilities, a study was undertaken to evaluate the existing facilities and estimate the costs required to:

(1) Modify the three major water pollution control plants to provide dissolved air flotation treatment for high peak combined flows.

(2) Construct additional dissolved air flotation treatment facilities for the treatment of combined sewer overflows and/or dry-weather flows.

The work carried out during the course of the study included a review of the plans of the existing facilities, determination of the basic design parameters for various flow quantities to be treated, a determination of facilities to be incorporated into the existing plants, preliminary cost estimates for the installation of these facilities, and construction cost estimates for new dissolved air flotation treatment plants.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

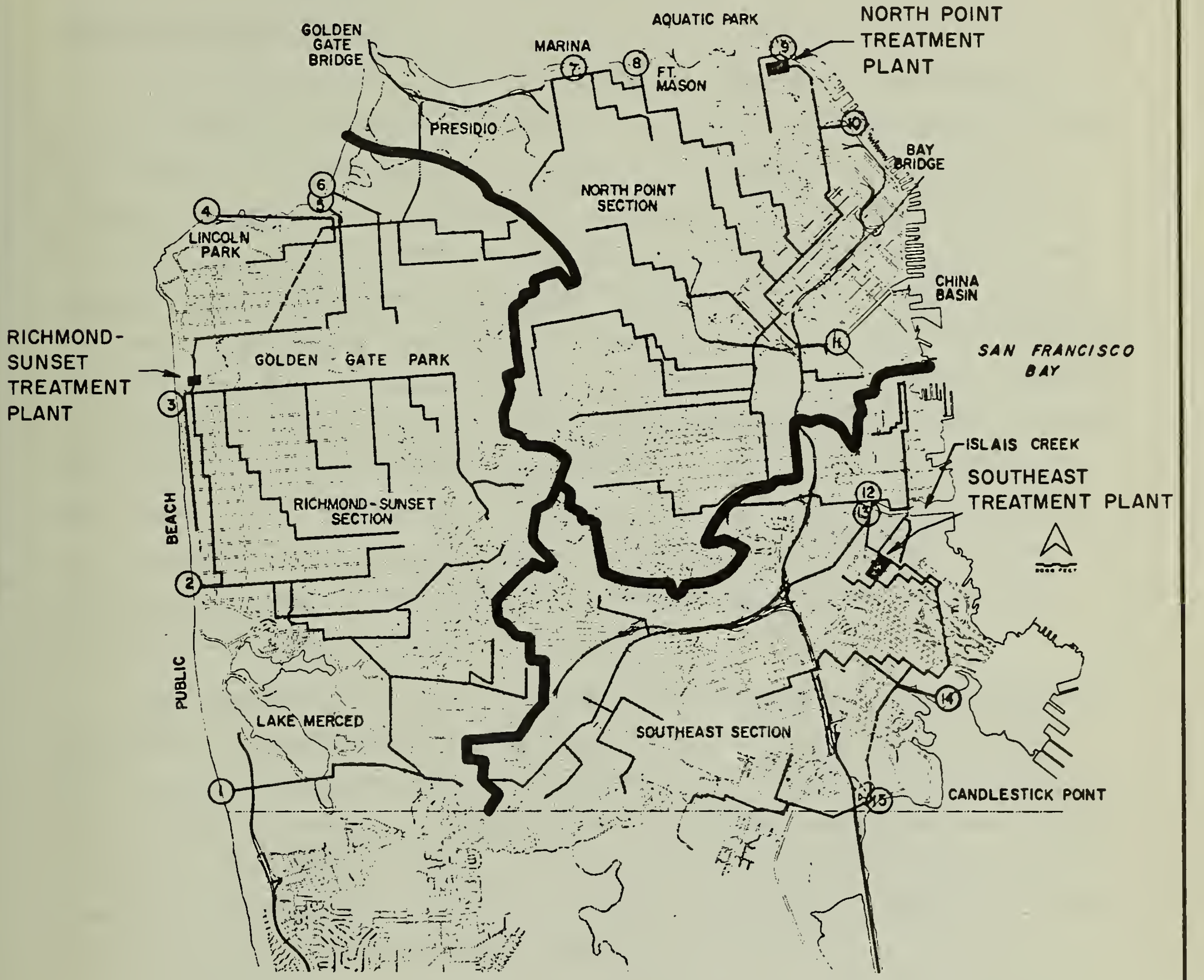
The Study Area, consisting of the City and County of San Francisco (hereafter called City), encompasses three distinct watershed areas. The Study Area is, therefore, divided into three districts along these natural drainage divisions. Each of the sewage systems serving these districts is a combined sewage system comprising both sanitary and storm sewers. On Figure II-1 is shown these sewage districts, the location of the three major treatment facilities, trunk sewers and 15 major combined sewer outfalls. There is a total of 41 separate combined sewer outfalls within the Study Area.

The Richmond-Sunset District encompasses an area of approximately 9,500 acres on the western side of San Francisco. The receiving water uses along the ocean boundaries are chiefly recreational. There are eight storm water outfalls in this district, five of which are identified as being major. An outfall is considered to be major if it has a calculated discharge for a 5-year storm of 500 cfs or larger (Reference 1).

The North Point District encompasses an area of approximately 9,000 acres in the northeastern sector of San Francisco, and includes the downtown section of the City as well as much of the industrial park area located south of the Bay Bridge Skyway. The receiving water usage varies from water contact sports in the Marina and Aquatic Park areas to ship berthing and fishing in the vicinity of the Central Basin. There are a total of 20 storm water outfalls in this district, five of which are defined as being major.

The Southeast District covers approximately 7,100 acres of residential and industrial land. Among the industries located in this zone are several which produce troublesome discharges, such as meat packing plants, rendering plants, tanneries, and breweries. Many of these industries operate on a noncontinuous basis and discharges often occur on a batch basis. The receiving water uses in this locale are restricted almost entirely to ship berthing, although some fishing takes place in the deeper waters. There are 13 storm water outfalls in this district, four of which are classified as major.

FIGURE II-1



SEWERAGE DISTRICTS, TRUNK SEWERS, AND MAJOR STORM OUTFALLS SAN FRANCISCO, CALIF.

CHAPTER III

SYSTEM CHARACTERISTICS

DISSOLVED AIR FLOTATION

Air flotation is a solids separation unit treatment process which has been used for many years in the chemical and mineral processing fields for concentrating and recovering solids. The dissolved air flotation process has been traditionally used in paper mills to accomplish pulp recovery, and also in industrial applications for separation of oils and greases from waste streams. Although the dissolved air flotation process has been traditionally considered for the separation of floatable materials from wastewaters, the reduced space requirements for the process, relative to that for gravity separation, has created considerable interest in using the process for suspended solids separation. The initial such use has been waste sludge thickening. The application of this unit process to the treatment of raw sewage or combined sewage flows is relatively new and there is a very limited amount of data available which can be used to define anticipated process performance.

The dissolved air flotation process is essentially a physio-chemical phenomenon in which small air bubbles interact with suspended materials such that the suspended material is carried to the water surface along with the rising bubbles. This air bubble-suspended solids mixture forms a float on the surface which can be removed by skimming. Formation and separation of floatable materials is usually enhanced by the use of various types of chemical additives and precursors.

Air bubbles are formed by placing air in solution at high pressure and then reducing the pressure, thus permitting the air to precipitate. Either the total flow or a portion of the flow is pressurized by means of a centrifugal pump. Air, also under pressure, is added to this pressurized flow which is then discharged to a saturation tank, where air which has not been dissolved is removed. This subprocess step is necessary to preclude the release of large air bubbles in the flotation unit. The pressure on the pressurized flow stream is reduced by means of a pressure reducing valve and the solution is reblended with the original waste stream at atmospheric pressure. The released air then acts

to carry the suspended materials to the surface.

WASTEWATER CHARACTERISTICS

The dry-weather wastewater quality of the influent to each of the City's treatment plants has been reported (Reference 2) for total suspended solids as follows:

Plant	Avg. TSS (mg/l)	Q (mgd)	TSS (lb/day)
North Point	193	59	95,000
Richmond-Sunset	324	20	54,000
Southeast	435	19	69,000

For wet-weather wastewater quality, flow rated concentrations for the Laguna Street System (Reference 1) has been used as follows:

TSS = 37.5 lbs per acre inch = 165 mg/l

PROCESS PERFORMANCE CHARACTERISTICS

Total Suspended Solids

The curves, shown in Figure III-1, depict the relationship between total suspended solids removal efficiency and liquid surface loading rate for the dissolved air flotation process. These curves have been developed from currently available information. Additional data should be available in the near future from the Baker Street dissolved air flotation facility and other demonstration projects which are now in progress. Data from these projects, when available, should be compared against the curves in Figure III-1 and appropriate adjustments made to the curves. The curves have been derived from data obtained in pilot plant studies in other areas (References 3 and 4) and adjusted for the characteristics of San Francisco sewage.

It is believed that the lower efficiency profile for the curve for wet-weather flows is due to the fact that the physio-chemical attachment and the transport forces which exist in the formation and flotation of the air bubble-particle aggregates are more effective in the high solids treatment situation than in the low solids situation. That is, an increased

level of suspended solids in the feed stream may be beneficial up to the point where the solids are present at such concentrations as to interfere with their free rise rate. Hindered flotation is thought to be a sub-process mechanism which is operative at suspended solids concentrations above 1,000 mg/l.

Pilot plant data are not available to draw corresponding curves for the removal of grease. In 1967 laboratory bench-scale experiments were conducted on combined sewage from the San Francisco sewerage system (Reference 1). These laboratory experiments suggest that dissolved air flotation is a potentially practical method for grease (as measured by HEM) removal and that surface loading rates in the range of 5,000 gpd/sq ft might be practical from a design standpoint to achieve 80 percent grease removals.

FLOATABLE MATERIALS

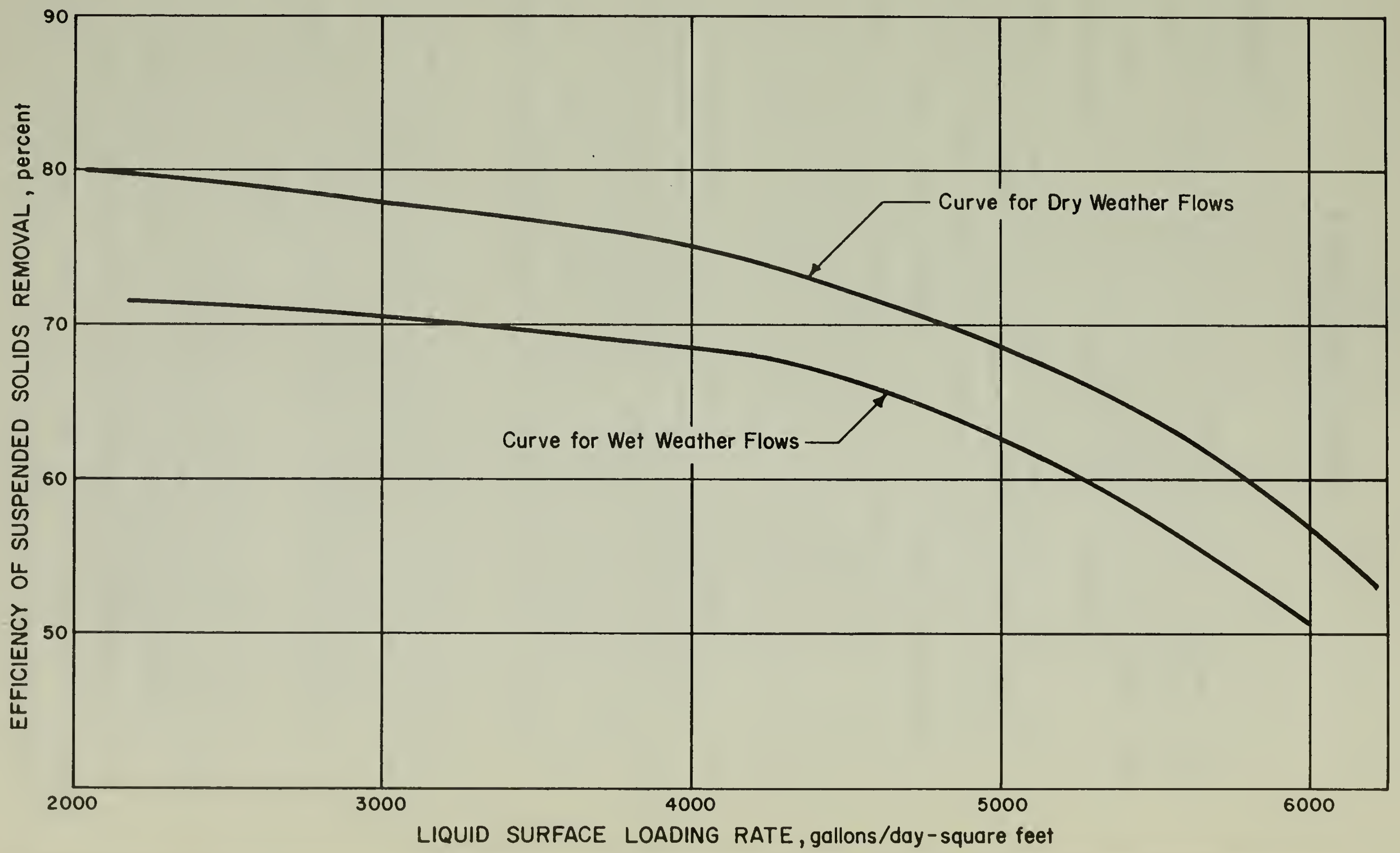
Materials which are floatable in the waste liquid will be substantially all removed, as determined by the chemical precursor. Materials which are potentially floatables, that is materials which will float in a liquid of a higher specific gravity such as sea water, should be removed to the same extent as grease.

BOD, PHOSPHATES, AND NITROGENOUS COMPOUNDS

These wastewater constituents and parameters are all secondary factors in terms of the character of the dissolved air flotation process. The concentration of these parameters and constituents will be affected only to the extent that they are associated with materials directly removed by the dissolved air flotation process. The lone exception may be phosphates, which could be precipitated by certain of the chemical additives.

FIGURE III-1

RELATIONSHIP BETWEEN TOTAL SUSPENDED SOLIDS REMOVAL EFFICIENCY, AND LIQUID SURFACE LOADING RATES DISSOLVED AIR FLOTATION OF CHEMICALLY - PRETREATED WASTEWATERS



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CHAPTER IV

RICHMOND-SUNSET PLANT

EXISTING FACILITIES

The Richmond-Sunset Water Pollution Control Plant is located in the southwest corner of the Golden Gate Park, reasonably well isolated from residential areas. This facility serves a tributary area of about 8,000 acres, the development of which is almost entirely residential.

Flow through the wastewater treatment system process train is entirely by gravity. Approximately 40 percent of the incoming sewage is pumped from the Mile Rock interceptor sewer to a receiving structure upstream of the plant. The balance of the flow arrives at the plant by gravity through two main interceptor sewers. Treated effluent is discharged to the Pacific Ocean through the Mile Rock Tunnel. This tunnel is 9 feet by 11 feet and discharges directly to the ocean at the base of a cliff in Lincoln Park in line with a prolongation of Forty-Eighth Avenue.

The plant was originally put into operation in 1939 and at that time had a peak wet-weather flow capacity of 45 mgd. It has since been enlarged and modified to its present peak wet-weather flow design capacity of 70 mgd. The dry-weather design capacity of this plant is 22.5 mgd, and the average 1969-70 dry-weather flow was 19 mgd (Reference 5). The peak dry-weather flow experienced at this plant was 39 mgd in 1968-69 (Reference 6).

The treatment process is conventional primary treatment consisting of screening, grit removal, primary sedimentation, and effluent disinfection prior to its discharge into the Ocean. Separated solids are digested, dewatered, and then used as a soil filler within the park. All treatment units are housed.

Primary settling takes place in five rectangular tanks. The first four tanks are identical units which were originally built as combination flocculation-sedimentation basins. A fifth tank was added in 1963 at which time the four existing basins were converted to conventional sedimentation basins. Each tank is now 135.5 feet by 35.5 feet with an average depth of 10 feet. An adjustable splitter arrangement divides the incoming

flow, diverting a portion to the east battery of three tanks and to the west battery of two tanks. Supernatant return from the raw sludge thickening tanks is discharged upstream of the splitter gate.

Each of the four original tanks is equipped with two sets of double longitudinal sludge collectors and a single cross collector for sludge removal. The fifth tank has only one set of double longitudinal collectors and a cross collector. The difference in arrangement is due to the fact that in the original four units the sludge hopper is located approximately 34 feet from the tank inlets between the original flocculation portion of the tank and the settling portion. In the newer tank the hopper is situated immediately adjacent to the inlet. All sludge collectors are of the continuous chain and flight type. Longitudinal collectors run continuously, collecting and transporting the settled sludge to the transverse valley where the continuously operating cross collector moves the sludge to a deep hopper located at the side of the tank. The sludge flows from this hopper by gravity to the concentration tanks.

Scum which accumulates on the water surface is collected in troughs located upstream of the effluent launders. Each scum trough is equipped with rubber bladed rotating skimmers. Scum is removed by the returning collector flights, except in the first 34 feet of the older tanks, where water sprays are used for moving the skimmings.

WASTE DISCHARGE REQUIRMENTS

The San Francisco Bay Regional Water Quality Control Board by Resolution No. 67-2, adopted on 19 January 1967, prescribed the following waste discharge requirements:

(1) No sewage discharged from the Richmond-Sunset sewerage zone (Figure II-1) shall cause any of the following conditions at any time:

(a) Deposited macroscopic particulate material or foam of waste origin at any place.

(b) Atmospheric odors recognizable as being of waste origin at any place outside the Richmond-Sunset Sewage Treatment Plant.

(c) Turbidity of discoloration in waters of the State at any place more than 200 feet from the Mile Rock Outfall.

(d) Dissolved sulfide concentrations greater than 0.1 mg/l within one foot below the surface of the Pacific Ocean at any place.

(e) At any place more than 100 feet from the Mile Rock Outfall:

Dissolved Oxygen	5.0 mg/l minimum
pH	6.5 minimum to 8.5 maximum

(f) At any place more than 300 feet from the Mile Rock Outfall:

No substance or combination of substances in concentrations deleterious to fish or other aquatic life.

The Regional Board will reconsider the area over which this specification applies when more specific parameters are available.

(g) Any ocean waters being protected for swimming, wading, or surfboarding pursuant to Paragraphs VII-V-2 and 3 above, to exceed those standards prescribed in Sections 7957 and 7958 of Title 17, California Administrative Code;

(2) No sewage discharged from the Mile Rock Outfall shall cause the receiving waters at the beaches within 1,500 feet of that outfall to exceed those standards prescribed in Sections 7957 and 7958 of Title 17, California Administrative Code at any time that the public is not effectively excluded from these beaches;

(3) The quality of the waste as determined at the discharge from the Richmond-Sunset Sewage Treatment Plant shall be maintained within the following limits at all times:

Any 24-hr composite sample made up of portions collected in proportion to rate of flow at time of collection:

Settleable Matter	0.5 ml/l/hr

Any grab sample:

Settleable Matter	1.0 ml/l/hr

As yet the Regional Board has not prescribed quantitative limits for grease in the waste stream.

QUALITY OF INFLUENT AND EFFLUENT

In August 1970 the results of a comprehensive sampling program (Reference 2) indicated the following data for total suspended solids (TSS) and grease as an average for a one-week period:

	TSS		Grease	
	lb/day	mg/l	lb/day	mg/l
Influent	54,000	324	9,400	56
Effluent	21,000	126	7,200	43

The average flow was 20 mgd.

PROPOSED DISSOLVED AIR FLOTATION FACILITIES

To add dissolved air flotation treatment capability to this plant, it is proposed to convert 70 feet (70 feet is approximately the greatest distance that dissolved air flotation skimmings may be transported without breaking down), of the sedimentation tanks into flotation compartments. To accomplish this it will be necessary to rearrange the existing sludge and scum conveyor system and construct a baffle wall at the end of the flotation section.

This size of flotation unit will provide a surface loading rate in the flotation compartment of 6,000 gpd/sq ft at the maximum hydraulic capcity of the plant.

A new skimmings collection system consisting of chain and flight equipment will be installed in each of the new flotation sections. The flights will move the skimmings along the water surface and transport them up a beach into a new skimmings trough. The skimmings would then be pumped from the trough to the existing scum collection system. Settled sludge will be removed by the existing sludge removal system.

On the four original tanks a center baffle will be required to confine the skimmings to the path of the skimmer flights.

The pressurization system for each flotation unit will consist of two vertical nonclog pumps with a capacity of 1,000 gpm at 60 psi in parallel, taking suction directly from the influent channel. One pump would be used for dry-weather flow conditions and both pumps would be

used for wet-weather flow. The pumps would each discharge into a five foot diameter by seven foot retention tank. Air would be added under pressure upstream of the retention tank. Provisions will be made to remove excess air that is not dissolved at the retention tank. The air saturated influent will then be piped to the flotation section, pass through a pressure reducing valve and be mixed with the balance of the influent stream.

A central air system would provide compressed air for all units. The air system would consist of two compressors each with a capacity of 100 cfm of standard air operating at a pressure ranging from 80 to 90 psi and an air storage tank. Air would be piped to each pump and regulated by a solenoid valve and a rotometer at each unit. The existing polymer feed system should be adequate for chemical feed for the dissolved air flotation system.

Automatic operation of these units is not comtemplated--the pumps and skimmers would be turned on by hand as needed.

The cost estimate for these facilities is shown in Table IV-1.

EXPECTED REMOVAL EFFICIENCIES

Based on the data developed for Figure III-1 the following removals are expected:

At 25 mgd dry-weather flow--70-75 percent removal of TSS.

At 70 mgd wet-weather flow--45-50 percent removal of TSS.

TABLE IV-1

RICHMOND-SUNSET PLANT
COST ESTIMATE FOR DISSOLVED AIR FLOTATION FACILITIES

Common Equipment		
Central Air Supply	$11,000	
Main Electrical Panel	15,000	
	$26,000	$ 26,000
Each Flotation Unit		
Mechanical Equipment		
Mechanical Skimmers	$10,000	
Skimmer Drive	2,000	
Skimmer Trough	2,000	
Float Pump	500	
Pressurization Equipment	16,200	
Pressure Reducing Valve	2,500	
Misc. Pipe and Fittings	2,000	
Installation of Mechanical Equipment	10,000	
Electrical	4,000	
Relocation of Sludge Skimmers	3,000	
Basin Modifications	5,000	
	$57,200 per unit	
Five Flotation Units		$336,000
Subtotal		$362,000
15% Construction Contingency		54,000
		$416,000
30% Engineering, Inspection & Administration		125,000
TOTAL		$541,000

CHAPTER V

NORTH POINT TREATMENT PLANT

EXISTING FACILITIES

The North Point Water Pollution Control Plant is located in the northern part of the City near the intersection of Bay and Embarcadero Streets. The plant was completed in 1951 and serves an area of approximately 9,000 acres. The tributary area is mostly residential in character, but also includes the downtown commercial area and some industrial development along the Port of San Francisco.

The treatment units are arranged in two groups of buildings with the pretreatment facilities, consisting of screens, grit tanks, and the influent pumping station on the south side of Bay Street. The sedimentation and postchlorination facilities are on the north side of Bay Street.

All sewage passing through the plant is pumped after screening and degritting. The effluent is discharged to San Francisco Bay through four 48-inch diameter outfalls which terminate 800 feet offshore, two at the end of Pier 33 and two at Pier 35. The discharges are submerged to a depth of ten feet below mean lower low water.

The dry weather design capacity of the plant is 65 mgd and the average dry weather flow is now 61 mgd. The maximum hydraulic capacity is 160 mgd.

Primary settling takes place in six combination preaeration-sedimentation tanks. The tanks are divided into two groups of three and housed in separate buildings. Each tank is 233 feet long, 38 feet wide with an average depth of 10.7 feet.

The first 74 feet of each tank is provided with four longitudinal rows of air diffusion plates for preaeration of the incoming sewage prior to sedimentation.

Effluent is collected from each primary sedimentation tank through four metal troughs provided with V-notch weirs on both sides. Each trough has a weir length of approximately 138 feet and extends approximately 86 feet toward the influent end of the tank.

Each tank is equipped with two longitudinal sludge collectors and a cross collector, all of the continuous chain and flight type. Longitudinal collectors run the entire length of each tank collecting and transporting the settled sludge to the effluent end of the tank where a cross collector moves it to a collection hopper. The raw sludge pump takes its suction from the hopper. Both longitudinal and cross collectors run continuously when tank is in service. Scum which accumulates on the water surface of the sedimentation portion of each tank is moved by water sprays to skimming troughs located between the preaeration and sedimentation section of each tank. Skimming troughs are of the manually operated tipping trough type.

Sludge and scum removed at this plant are pumped to the Southeast Plant for disposal.

WASTE DISCHARGE REQUIREMENTS

The San Francisco Bay Regional Water Quality Control Board by Resolution No. 7-17 adopted 26 March 1970 prescribed the following waste discharge requirements for the receiving waters:

(1) The treatment or disposal of waste shall not create a nuisance as defined in Section 13050(m) of the California Water Code.

(2) The discharge shall not:

(a) Unreasonably affect any of the protected beneficial water uses resulting from:

Floating, suspended, or deposited macroscopic particulate matter, or foam in waters of the State at any place;

Bottom deposits at any place;

Aquatic growths at any place;

Alteration of temperature, turbidity, or apparent color beyond present natural background levels in waters of the State at any place.

(b) Cause visible, floating, suspended, or deposited oil or other products of petroleum origin in waters of the State at any place.

(3) The discharge shall not cause the waters of the State to exceed

the following limit of quality at any place within one foot of the surface at any time:

(a) Dissolved Oxygen - 5.0 mg/l minimum;

(b) Dissolved Sulfides - 0.1 mg/l maximum;

(c) pH - 7.0 minimum; 8.5 maximum;

(d) Coliform organisms - 240 MPN/100 ml, median of five consecutive samples, maximum 10,000 MPN/100 ml, any single sample, maximum.

Whenever either of these bacterial values is exceeded in the receiving water for any reason they shall both be met instead in the waste at some point in the treatment process. The discharger may demonstrate compliance in the waste stream as an optional alternative.

The Board will accept proof of effective effluent disinfection in terms of factors other than bacterial concentrations if the discharger documents a sound statistical correlation between such factors and bacterial analysis, and provided the conditions of sewage strength and treatment do not change from the demonstration period;

(e) Nutrients - to be prescribed at the earliest practicable date.

(f) Other substances - any one or more substances in concentrations that impair any of the protected beneficial water uses or make aquatic life or wildlife unfit or unpalatable for consumption.

The waste stream discharged to waters of the State shall meet these quality limits at all times:

(1) In any grab sample:

Settleable matter:

The arithmetic average of any six or more samples collected on any day - 0.5 ml/l/hr maximum;

The arithmetic average of 80 percent of all individual samples collected during maximum daily flow over any

30-day period - 0.4 ml/l/hr minimum;

At this time this Board considers the above two settleable matter limits to be goals rather than requirements.

Any sample - 1.0 ml/l/hr maximum.

(2) In any representative 24-hour composite sample:

Toxicity: the concentration of the waste itself at any place within one foot of the surface of the receiving waters shall not exceed 10 percent of the 96-hour TL_m concentration of the waste as discharged.

(3) Five-day, 20°C BOD - Whenever the receiving water dissolved oxygen (DO) concentration prescribed above is not met, the BOD removal from the waste, as demonstrated by analyses of 24-hour composite samples of influent and effluent, shall be increased sufficiently to maintain said DO concentration, but BOD removal during any 21 or more days is not required to exceed:

Average - 90 percent;

Not more than two consecutive daily determinations shall indicate BOD removals less than - 80 percent.

The Regional Board also notified the City in the same resolution that the Board intended to adopt numerical goals for transparency, floatables, grease, and settleable matter.

Resolution No. 70-2 of the Regional Board adopted 29 January 1970, in prescribing requirements for waste discharges from wet weather diversion structures for the North Point Sewage Zone prescribed the following:

(1) All waste streams discharged to waters of the State shall meet these quality limits at all times:

(a) In any representative sample:

Toxicity: survival of test fishes in 96-hour bioassay of the waste as discharged;

Any sample - 75 percent minimum;

Average of any three or more consecutive samples collected during any 21 or more days - 90 percent minimum.

(b) In any grab sample:

Grease - 25 mg/l maximum;
Settleable matter - 1.0 ml/l/hr maximum.

This Board considers these two limits to be goals rather than requirements and will consider requirements for settleable matter, grease, and/or floatable matter after reviewing additional information on the costs and other information relative to the feasibility of compliance therewith.

It is presumed that the above requirements are also goals for the waste stream from this treatment plant.

QUALITY OF INFLUENT AND EFFLUENT

In August of 1970 a comprehensive sampling program (Reference 1) revealed the following for total suspended solids (TSS) and grease as an average for a one-week period:

	TSS		Grease	
	lb/day	mg/l	lb/day	mg/l
Influent	95,000	193	16,000	101
Effluent	45,000	92	19,000	39

The average flow was 59 mgd.

DISSOLVED AIR FLOTATION FACILITIES

To add dissolved air flotation capability to this plant, it is proposed to convert the preaeration sections into flotation compartments. Preaeration would be discontinued. This section, 74 feet long and 38 feet wide, will provide a dissolved air flotation surface loading rate of approximately 5,000 gpd/sq ft at a flow of 80 mgd. At the plant's maximum hydraulic capacity of 160 mgd, the dissolved air flotation surface loading rate would be approximately 10,000 gpd/sq ft. In making additions to an existing plant there are certain compromises that must be made. In this case, working within the constraints of the existing basins and the maximum practical distance that dissolved air flotation float may be transported without breaking up, the overflow rates are higher than may ordinarily

be desirable. The expected removals, at the maximum hydraulic capacity of this plant, are accordingly reduced.

A float collection system consisting of chain and flight equipment will be installed in each of the new flotation sections. In each of the flotator sections it will be necessary to construct a center baffle to confine the float to the path of the skimmer. The flights will move the float along the water surface and transport them up a beach into a new skimming trough. The skimmings would then be pumped from the trough to the existing scum collection system. Settled sludge would be removed by the existing sludge removal system. Chemical feed equipment exists at this plant for feeding polymers.

The pressurization system for each flotation unit will consist of two vertical nonclog pumps with a capacity of 1,700 gpm at 60 psi taking suction directly from the influent channel. One pump would be used for dry weather flow conditions and both pumps would be used for wet weather flows. The pumps would each discharge into a 6.5-foot diameter by 7-foot high retention tank. Air would be added under pressure upstream of the retention tank. Provisions will be made to remove excess air that is not dissolved at the retention tank. The air saturated influent will then be piped to the flotation section, pass through a pressure reducing valve and be mixed with the balance of the influent stream.

A central air system would provide air for all units. The air system would consist of an air storage tank and two compressors, each with a capacity of 200 cfm of standard air operating at a pressure ranging from 80 to 100 psi. Air would be piped to each pump and regulated by a solenoid valve and a rotometer at each unit.

Automatic operation of these units is not contemplated. The pumps would be turned on and off as needed. The skimming system would operate continuously.

The estimated cost of these facilities is shown in Table V-1.

EXPECTED REMOVAL EFFICIENCIES

Based on the data developed for Figure III-1, the following removals are expected:

At 80 mgd dry-weather flow--65-75 percent removal of TSS

At 160 mgd wet-weather flow--35 percent removal of TSS

TABLE V-1

NORTH POINT PLANT
COST ESTIMATE FOR DISSOLVED AIR FLOTATION FACILITIES

Common Equipment		
Central Air Supply	$12,000	
Main Electrical Panel	15,000	
	$27,000	$ 27,000
Each Flotation Unit		
Mechanical Equipment		
Mechanical Skimmers	$11,000	
Skimmer Drive	2,000	
Skimmer Trough	2,000	
Float Pump	500	
Pressurization Equipment	23,600	
Pressure Reducing Valve	2,500	
Misc. Pipe & Fittings	2,000	
Installation of Mechanical Equipment	10,000	
Electrical	4,000	
Basin Modifications	6,000	
	$63,600 per unit	
Six Flotation Units		$381,600
Subtotal		408,600
15 % Construction Contingencies		61,200
		$469,800
30% Engineering, Inspection & Administration		140,000
TOTAL		$609,800

CHAPTER VI

SOUTHEAST PLANT

The Southeast Water Pollution Plant is located in the heavy industrial area in the southeast corner of the City. The facility serves a tributary area of approximately 7,000 acres. The sewage is primarily industrial with some residential contributions.

All sewage passing through the plant is pumped after screening and degritting. The effluent is discharged through a multiport diffuser located on a line parallel to and 550 feet north of Islais Creek. The diffusers are located between 500 and 800 feet offshore at a depth of 50 feet below mean lower low water. At times of high flows it is necessary to pump the effluent through the outfall.

The dry-weather design capacity of the plant is 30 mgd, and the average dry-weather flow during 1969-70 was 13 mgd. The maximum hydraulic capacity is 70 mgd.

The plant provides conventional primary treatment consisting of prechlorination, screening, grit removal, preaeration, primary sedimentation, and postchlorination.

Sludge and scum removed at this plant, as well as that removed at the North Point Plant, are processed by gravity thickening, sludge digestion and dewatering. Dewatered digested sludge is trucked to the City landfill for disposal.

Discharge from the grit tanks flows into four combination preaeration-sedimentation tanks. These units are arranged in pairs in two separate buildings. The sludge collection system in two of these tanks is now being modified by changing the sludge collection pit from the effluent end of the tanks to the center of the tanks.

Each preaeration-sedimentation basin is 262 feet long, 37 feet wide, and has an average depth of 11 feet. The City is now in the process of modifying these basins; when modified, the tanks will be only 247 feet long, the last 15 feet will be abandoned. The first 69 feet of each tank is provided with air diffusers for preaeration of the incoming sewage prior to sedimentation.

Four metal launders provided with adjustable side weirs are used to collect the effluent from the sedimentation tanks. Each launder has a weir length of approximately 173 feet, extends approximately 92 feet toward the influent end of the tank, and discharges through a 30-inch diameter submerged pipe into a common collection channel. In the modified units, effluent will be collected through a system of 56 three-inch vertical pipes located along the bottom of the launders. Prior to the beginning of the present modification, all preaeration-sedimentation tanks were equipped with two full-length longitudinal collectors and a cross collector for sludge collection. The cross collector was located at the effluent end of each tank. Modifications to the two tanks in Building One will relocate the cross collector to the middle of the tanks with the result that each tank will have two sets of much shorter longitudinal collectors and the effluent end collector will be moving the sludge away from instead of towards the effluent end of the tanks. All sludge collectors are and will continue to be of the continuous chain and flight type. Existing tank collectors are driven by a single common motor for each tank. Modified tank collector drives will be provided with individual speed adjustable hydraulic motors for each collector. Hydraulic power units are to be located in the existing sludge control building.

Scum collected on the water surface of the existing sedimentation tanks, upstream of the effluent launders, is moved by water sprays to a tipping trough located just downstream from the preaeration segment of each tank. Scum rising to the surface in the vicinity of the effluent launders is isolated from the weirs by redwood outboard baffles and collected near the tank end wall by manually adjustable skimming troughs. Two skimming troughs are provided for each tank. Modifications presently underway to the tanks in Building One will result in the replacement of all existing skimming facilities with two full-width scum skimmers located at both ends of the effluent launders. The unit at the upstream end of the launders will be an electrically driven, double rubber blade rotating skimmer. The one at downstream end will be of the manually operated tipping trough type.

WASTE DISCHARGE REQUIREMENTS

The San Francisco Bay Regional Water Quality Control Board by Resolution

No. 69-44 adopted 25 September 1969 prescribed the following waste discharge requirements for the receiving waters:

(1) The discharge of the waste shall not cause:

(a) Atmospheric odors recognizable as being of waste origin at any place outside the discharger's treatment plant.

(b) Unsightliness, nor damage to any of the protected beneficial water uses resulting from:

Floating, suspended, or deposited macroscopic particulate matter, foam, oil, or grease in waters of the State at any place; floating oil shall be considered present if in sufficient quantity to cause iridescence;
Bottom deposits at any place;
Aquatic growths at any place;
Significant variation in temperature beyond natural background levels;
Essentially any visible evidence of the waste attributable to floatables, color, or turbidity.

(c) Bacterial concentration in waters of the State at any place within one foot of their surface to exceed the limits prescribed in Section 7958, Title 17, California Administrative Code, at any time; when this bacterial concentration is exceeded in the receiving waters for any reason it shall be met instead in the waste at some point in the treatment process and the discharger may do so as an optional alternate; the Board will accept proof of effective effluent disinfection in terms of factors other than bacterial concentrations if the discharger documents a sound statistical correlation between such factors and bacterial analysis.

(2) Water of the State to exceed the following limit of quality at any place within one foot of the surface at any time:

Dissolved Oxygen	5.0 mg/l minimum
Dissolved Sulfides	0.1 mg/l maximum
pH	7.0 minimum - 8.5 maximum

Any one or more substances in concentrations that impair any of the protected beneficial water uses or make aquatic life or wildlife unfit for consumption.

The waste discharged shall meet these quality limits at all times:

(1) In any grab sample:

Settleable matter

The arithmetic average of any six or more samples collected on any day	0.5 ml/l/hr maximum
80 percent of all individual samples collected during maximum daily flow over any 30-day period	0.4 ml/l/hr maximum

At this time this Board considers the above two settleable matter limits to be objectives rather than requirements.

Any sample	1.0 ml/l/hr maximum

(2) In any representative 24-hour composite sample:

Toxicity: The concentration of the waste itself at any place within one foot of the surface of the receiving waters	10 percent of the 96-hour TL_m concentration of the waste as discharged, maximum

(3) Five-day, 20°C BOD - Whenever the receiving water dissolved oxygen (DO) concentration prescribed above is not met, the BOD removal from the waste, as demonstrated by analyses of 24-hour composite samples of influent and effluent, shall be increased sufficiently to maintain said DO concentration, but BOD removal during any 21 or more days is not required to exceed:

Average	90 percent
Not more than two consecutive daily determinations shall indicate BOD removals less than	80 percent

OTHER REQUIREMENTS AND CONDITIONS

The discharger is required to submit the following reports to the Regional Board on or before 30 November 1969:

(1) A firm and detailed time schedule for the preparation of a preliminary engineering report and cost estimates for facilities needed to comply with the above requirements for floatables, turbidity, discoloration and setteable matter. For the purposes of said report the discharger shall use the following numerical ranges:

Reduction in receiving water clarity	5 to 30 percent in 90 percent of the determinations made on any day in the area of greatest turbidity
Floatables in the receiving water at any place	10 to 50 mg/square meter
Grease in the effluent	5 to 30 mg/l
Settleable matter	Those objectives and requirements listed above.

(2) A firm and detailed time schedule for all investigations necessary to implement a program to minimize all discharges of waste which would not comply with requirements prescribed herein and which would result from equipment or power failure. (References: Section 13055, California Water Code and this Board's Resolution No. 398.)

This Board will adopt, prior to 31 December 1970, numerical objectives for transparency, floatables, grease, and settleable matter as requirements. The Board expects the discharger to report on the type of facilities needed and the cost of complying with various numerical values within the above ranges.

Resolution No. 70-3 adopted 29 January 1970 in prescribing requirements for waste discharges from wet-weather diversion structures prescribed the following:

> All waste streams discharged to waters of the State shall meet these quality limits at all times:
>
> In any representative sample:

Toxicity: survival of test fishes in 96-hour bioassay of waste as discharged

Any sample	75 percent minimum
Average of any three or more consecutive samples collected during any 21 or more days	90 percent minimum

In any grab sample:

Grease	25 mg/l maximum
Settleable matter	1.0 ml/l/hr maximum

This Board considers these two limits to be goals rather than requirements and will consider requirements for settleable matter, grease, and/or floatable matter after reviewing additional information on the costs and other information relative to the feasibility of compliance therewith.

QUALITY OF INFLUENT AND EFFLUENT

The results of a previous study (Reference 1) indicated that typical values of total suspended solids (TSS) and grease during one week in August 1969 were as follows:

	TSS		Grease	
	lb/day	mg/l	lb/day	mg/l
Influent	69,000	435	16,000	101
Effluent	47,000	298	11,000	70

DISSOLVED AIR FLOTATION FACILITIES

To add dissolved air flotation to this plant, it is proposed to convert the preaerator sections into flotation compartments. Preaeration would be discontinued. This section, 69 feet long and 37 feet wide, will provide a surface loading rate of approximately 7,000 gpd/sq ft at the maximum hydraulic capacity of the plant and 3,000 gpd/sq ft at the design capcity of 30 mgd.

A float collection system consisting of chain and flight equipment will be installed in each of the new flotation sections. A center baffle will be constructed in each of the flotators to confine the float to the

path of the skimmer. The flights will move the float along the water surface and transport them up a beach into a new skimmings trough. The skimmings would then be pumped from the trough to the existing scum collection system. The settled sludge would be removed by the existing sludge removal system.

Because chemical feed equipment exists at this plant for feeding polymers, no new equipment is proposed. A change of the type of polymer may be necessary for the dissolved air flotation process.

The pressurization system will consist of two vertical nonclog pumps with a capacity of 1,200 gpm at 60 psi, taking suction directly from the influent channel of each basin. One pump would be used for dry-weather flow conditions and both pumps would be used for wet-weather flow conditions. The pumps would each discharge into a 5.5-foot diameter by 7-foot high retention tank. Air would be added under pressure upstream of the retention tank. Provisions will be made to remove the undissolved air at the retention tank. The air saturated influent will then be piped to the flotation section, pass through a pressure reducing valve and be mixed with the balance of the influent stream.

A central air system would provide air for all units. The air system would consist of an air storage tank and two compressors each with a capacity of 100 cfm of standard air operating at a pressure ranging from 80 to 100 psi. Air would be piped to each pump and regulated by a solenoid valve and a rotometer at each unit.

Automatic operation of these units is not contemplated. The pumps would be turned on and off as needed and the skimming system would operate continuously.

The estimated cost for these facilities is shown in Table VI-1.

EXPECTED REMOVAL EFFICIENCIES

It is evident from the results of the tests performed on the overflows from the sludge thickeners and the elutriation facilities (Reference 1) that a plant effluent meeting the requirements of the Regional Board cannot be met without removing the suspended solids and grease from these sources rather than recirculating them through the treatment process.

Based on the data developed for Figure III-1 and assuming the solids once removed by the dissolved air flotation units are not returned back to the system via the elutriation overflow or the sludge thickeners overflow the following removals are expected:

At 30 mgd dry-weather flow--70-75 percent removal of TSS

At 70 mgd wet-weather flow--40-45 percent removal of TSS

TABLE VI-1

SOUTHEAST PLANT

COST ESTIMATE FOR DISSOLVED AIR FLOTATION FACILITIES

Common Equipment		
Control Air Supply	$11,000	
Compressor Building	15,000	
Main Electrical Panel	15,000	
	$41,000	$ 41,000
Each Flotation Unit		
Mechanical Equipment		
Mechanical Skimmers	$10,000	
Skimmer Drive	2,000	
Float Trough	2,000	
Float Pump	500	
Pressurization Equipment	17,600	
Pressure Reducing Valve	2,500	
Misc. Pipe & Fittings	3,000	
Installation of Mechanical Equipment	10,000	
Electrical	4,000	
Basin Modifications	5,000	
	$56,600 per unit	
Four Flotation Units		$226,400
Subtotal		$267,400
15% Construction Contingencies		40,600
		$308,000
30% Engineering, Inspection, & Administration		92,000
TOTAL		$400,000

CHAPTER VII

CONSTRUCTION COSTS OF NEW FACILITIES FOR TREATMENT OF COMBINED WASTES

Cost information presented in this chapter has been developed to permit the determination of the cost of constructing new dissolved air flotation facilities over a wide range of capacities.

Cost estimates have been made for plants ranging in size from 25 mgd to 1,000 mgd using hydraulic loading rates of 2,000 and 5,000 gpd/sq ft. These estimates are shown in Tables VII-1 and VII-2 and are the bases for the curves shown in Figure VII-3. By utilizing these curves in conjunction with those presented in Chapter III, costs for dissolved air flotation facilities for a wide range of flow capacities and desired suspended solids removal efficiencies can be estimated.

The cost estimates for the treatment plants do not include the cost of float or sludge disposal. It has been assumed that the material removed from the flotation units will be pumped back to the interceptor sewer for final disposal at one of the existing treatment plants.

In the construction of facilities for the treatment of combined sewerage overflows, it may be necessary to construct pumping stations at certain locations. A curve for estimating construction costs for sewage pumping stations is presented in Figure VII-5. Additionally, the curves presented in Figure VII-4 may be used for estimating the cost of ocean outfalls.

In the preparation of all of the estimating curves, no allowance has been made for the cost of land or right-of-ways. All estimates include an allowance for engineering, overhead, inspection, and contract administration. Special foundation work, such as piles, special foundations, or site dewatering, have not been included in the estimates as these items would be peculiar to the specific site selected for construction.

DISSOLVED AIR FLOTATION FACILITIES ESTIMATE

The construction costs for dissolved air flotation facilities were based on the process flow diagram, illustrated in Figure VII-1, and the general plant layout, illustrated in Figure VII-2. The flotation units

TABLE VII-1

CONSTRUCTION COST ESTIMATE FOR TREATMENT OF COMBINED SEWER OVERFLOWS UTILIZING DISSOLVED AIR FLOTATION

(5,000 gal/sq ft/day)
(dollars in thousands)

Item	25 mgd	50 mgd	200 mgd	500 mgd	1,000 mgd
Mechanical Equipment					
Bar Screens	13	15	60	120	200
Aerated Grit Chamber	10	15	50	100	200
Flotation Tank Mechanism	55	110	250	600	1,200
Pressurization System	40	80	250	500	1,000
Settleable Pumps	3	5	14	35	70
Floatable Pumps	4	5	16	40	80
Screening Conveyor	15	15	30	60	120
Chemical Feed	30	50	75	100	150
Regulating Gates	20	40	120	200	400
Total Mechanical Equipment	190	335	865	1,755	3,420
Erection Mechanical Equipment	63	100	260	525	1,000
Instrumentation and Controls	115	125	175	270	415
Control Building	100	100	100	100	100
Pipe Valves and Fittings	63	100	260	525	1,000
Earthwork	40	60	180	400	750
Concrete	540	800	1,800	4,200	8,400
Electrical	75	150	400	800	1,600
	1,186	1,770	4,040	8,575	16,685
Miscellaneous 15%	180	270	610	1,070	2,280
	1,366	2,040	4,650	9,645	18,965
Engineering, Inspection, Contingencies, and Administration	410	612	1,395	2,655	5,220
	1,776	2,652	6,045	12,300	24,185
Call	1,800	2,700	6,000	12,500	24,000

TABLE VII-2

CONSTRUCTION COST ESTIMATE FOR TREATMENT OF COMBINED SEWER OVERFLOWS UTILIZING DISSOLVED AIR FLOTATION

(2,000 gal/sq ft/day)
(dollars in thousands)

Item	25 mgd	50 mgd	200 mgd	500 mgd	1,000 mgd
Mechanical Equipment					
Bar Screens	13	15	60	120	200
Aerated Grit Chamber	10	15	50	100	200
Flotation Tank Mechanism	90	180	600	1,460	2,900
Pressurization System	40	80	250	500	1,000
Settleable Pumps	3	5	14	35	70
Floatable Pumps	4	5	16	40	80
Screening Conveyor	15	15	30	60	120
Chemical Feed	30	50	75	100	150
Regulating Gates	20	40	120	200	400
Total Mechanical Equipment	225	405	1,215	2,615	5,120
Erection Mechanical Equipment	68	120	360	780	1,500
Intrumentation and Controls	115	125	175	270	415
Control Building	100	100	100	100	100
Pipe Valves and Fittings	68	120	360	780	1,500
Electrical	75	150	400	800	1,600
Earthwork	74	111	300	740	1,450
Concrete	820	1,340	3,500	8,200	16,400
	1,545	2,471	6,410	14,285	28,085
Miscellaneous 15%	230	340	960	2,150	4,200
	1,775	2,811	7,370	16,435	32,285
Engineering, Inspection, Contingencies, and Administration	532	781	2,210	4,930	9,695
	2,307	3,592	9,580	21,365	41,980
Call	2,300	3,600	9,600	21,500	42,000

may either be rectangular, circular, or square in configuration. The units have been sized for hydraulic loading rates of 2,000 gpd/sq ft and 5,000 gpd/sq ft.

The major items of mechanical equipment were selected for a 50 mgd plant. Selection of equipment for other sizes of plants was then based on appropriate modifications.

Erection of mechanical equipment was estimated at approximately 30 percent of the cost of the equipment on the basis of experience and also consultation with suppliers who have indicated that this is a conservative estimate.

Pipe, valves, and fittings were estimated as 30 percent of the mechanical equipment. This item could vary from 15 to 30 percent of the mechanical equipment depending on the complexity of both the mechanical equipment and the piping layout.

Instrumentation and controls were based (in part) on the Baker Street dissolved air flotation facility and in part on experience. This item can, of course, vary greatly, depending on the degree of sophistication and automation desired. It is believed that the estimates used will supply adequate instrumentation and controls for a functional automatic plant.

Architectural treatment has been assumed to be in the order of magnitude of that used for the Baker Street dissolved air flotation facility. This would be sufficient to provide all buildings, walls around the plant, or construction of major underground facilities.

Concrete was estimated assuming one-foot thick walls, four foot thick bottoms, and a two foot cover. The unit cost of concrete was estimated to vary from $235 per cubic yard for volumes less than 3,000 cubic yards to $125 for volumes greater than 25,000 cubic yards.

Earthwork was estimated by calculating the surface area of the flotation units, assuming a 20-foot deep excavation and multiplying by a unit cost varying from $10 per cubic yard for volumes less than 9,000 cubic yards to $4 per cubic yard for volumes in excess of 70,000 cubic yards. The unit prices were selected to allow for miscellaneous excavations not computed. Excavation prices would vary depending on the location of the site, the type of material to be excavated, the volume to be excavated,

and the volume and location of the disposal site.

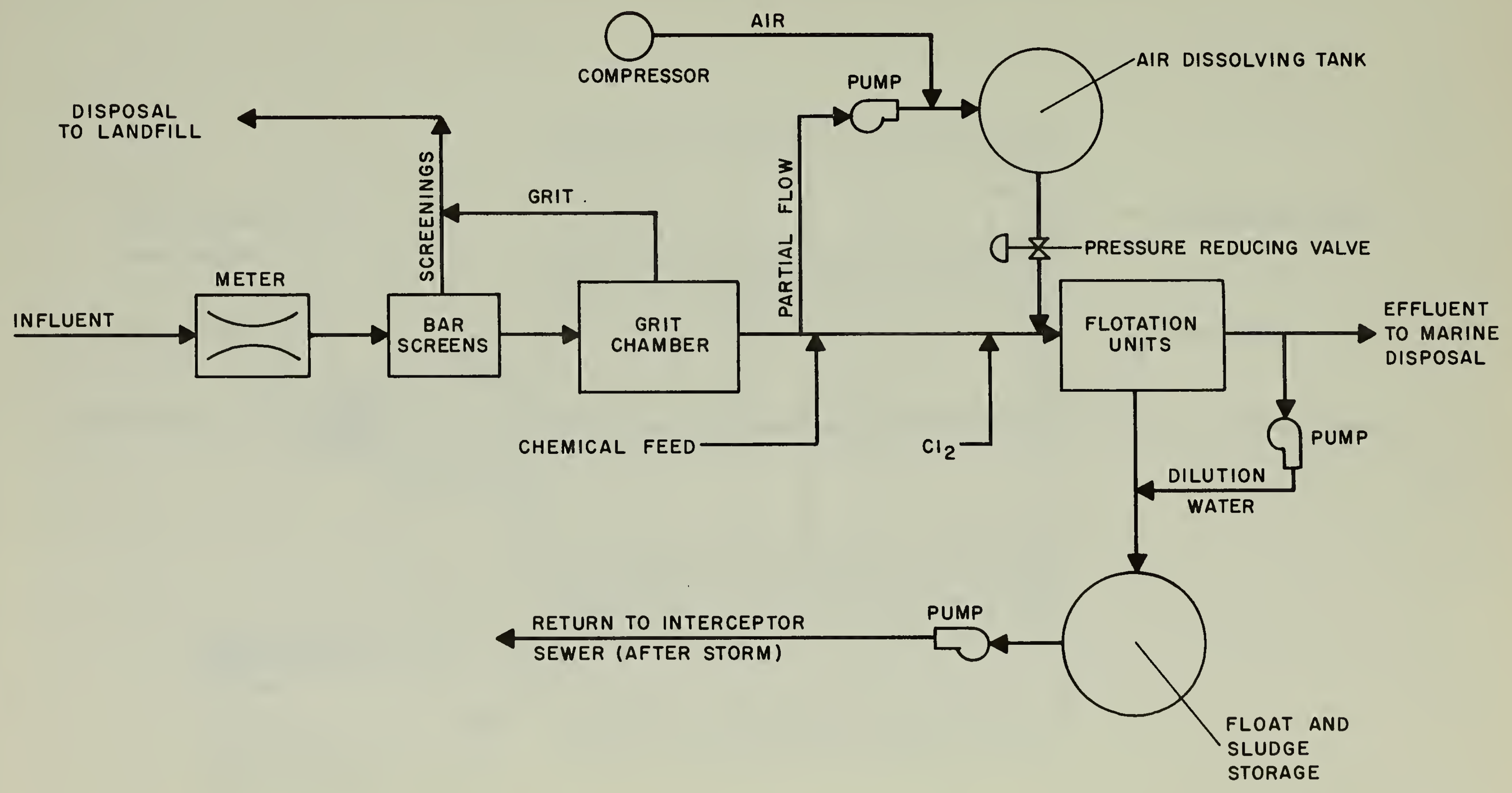
To all of the above figures approximately 15 percent was added for miscellaneous items and to allow an additional contingency for possible special architectural treatment of certain units. Thirty percent was then added to the construction estimate for engineering, inspection, contingencies, and project administration.

As an example, an estimate developed on this basis for a 25 mgd dissolved air flotation plant using Table VII-1 or Figure VII-3 would compare reasonably with the actual cost of the Baker Street dissolved air flotation facility as follows:

(1)	Actual Contractor Bid		$2,062,510
	Less Special Items:		
	Cofferdam and dewatering	$152,000	
	Outfall	300,000	
	Influent sewer	83,000	
	Bypass	17,500	
	Demolish old sewer	17,500	
	Force main	45,000	615,000
			$1,447,510
	Less concrete in special foundation		150,000
			$1,297,510
	Plus 30 percent Engineering, Inspection, and Administration		389,100
	Construction Cost Excluding Special Items		$1,686,610
(2)	Estimate for 25 mgd dissolved air flotation facility using Table VII-1 or Figure VII-3		$1,800,000

FIGURE VII-1

FLOW DIAGRAM - DISSOLVED AIR FLOTATION FACILITIES FOR STORM WATER OVERFLOWS OF COMBINED SEWERS



[illegible]

FIGURE VII - 2

DISSOLVED AIR FLOTATION FACILITIES LAYOUT

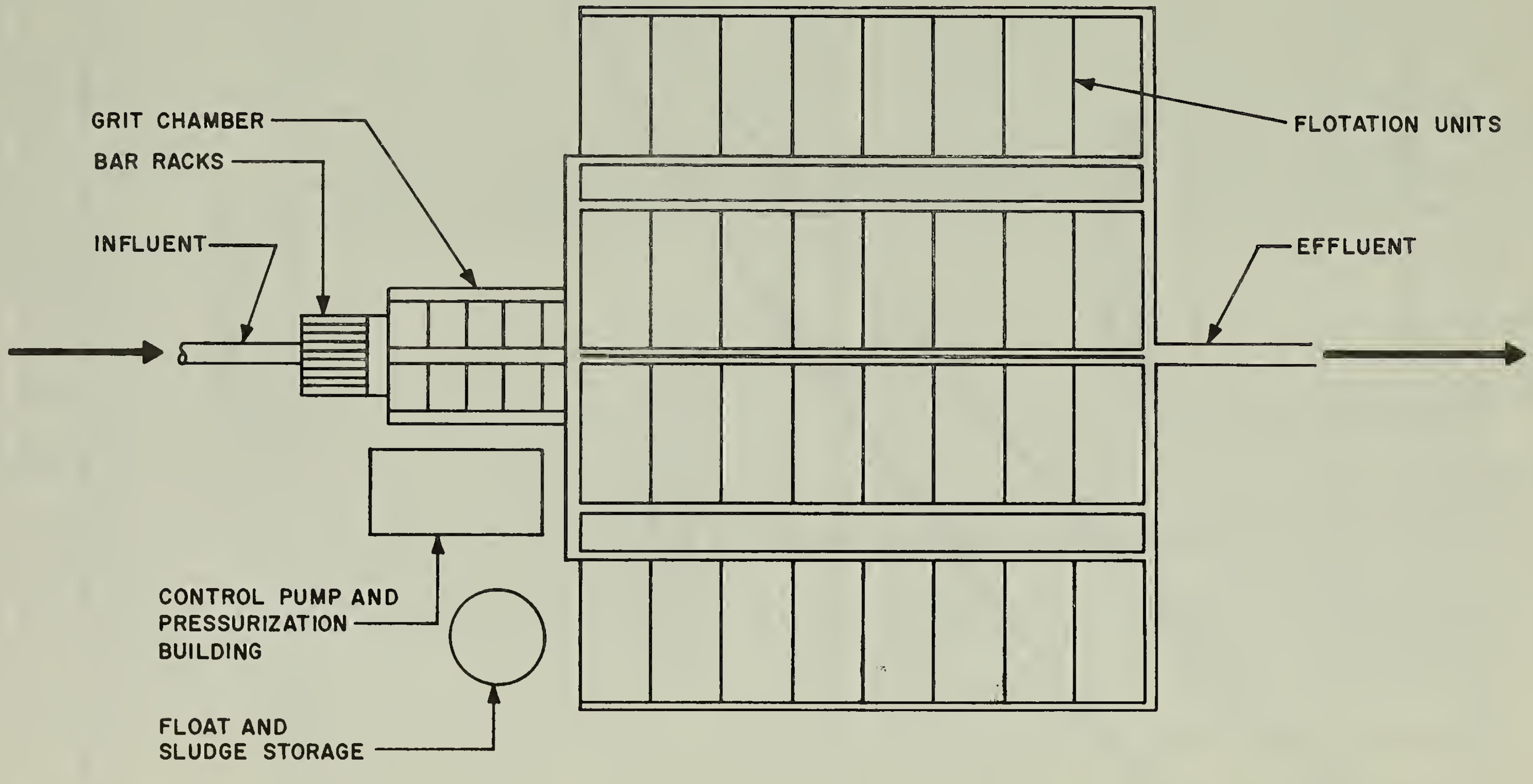
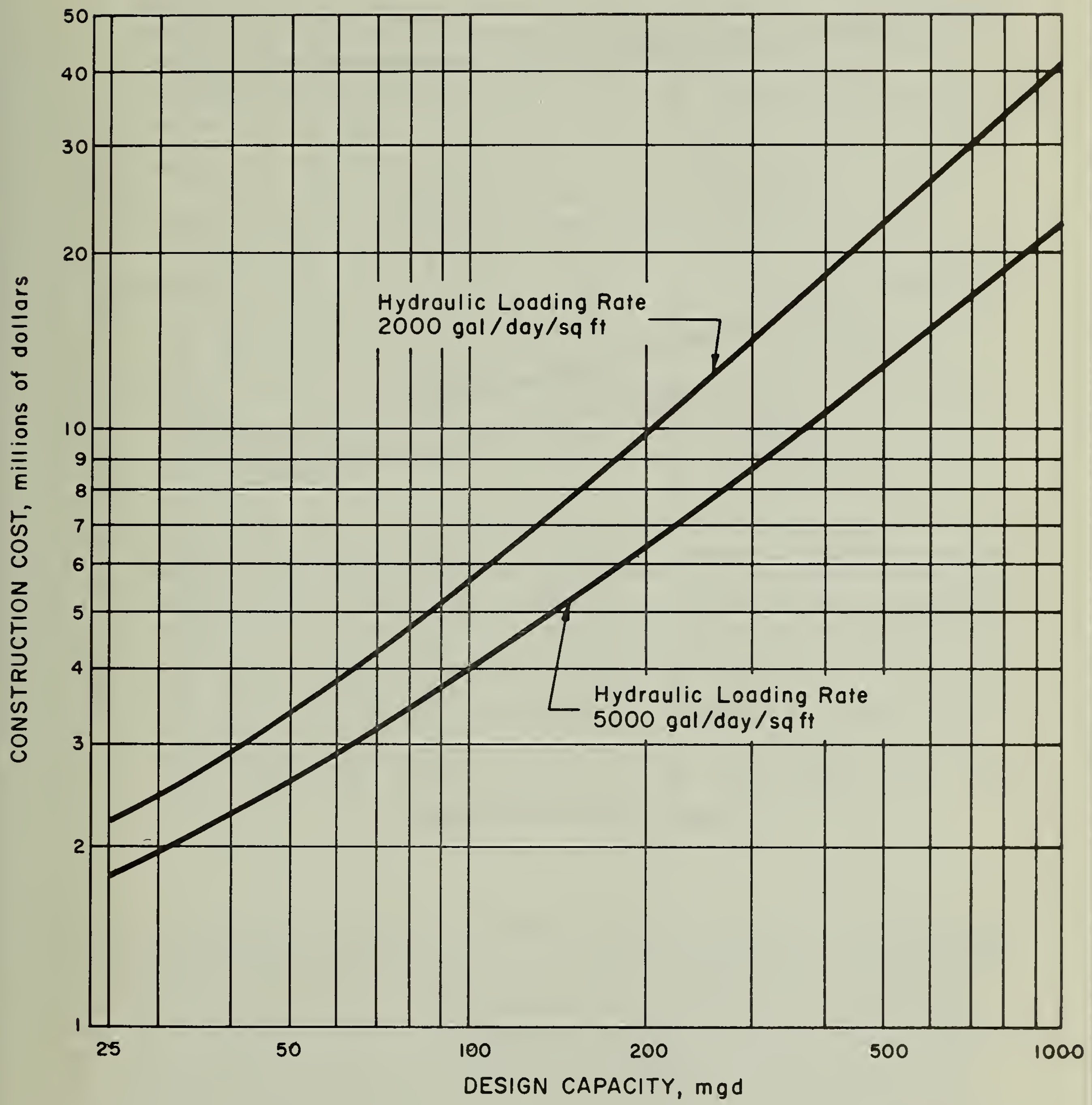


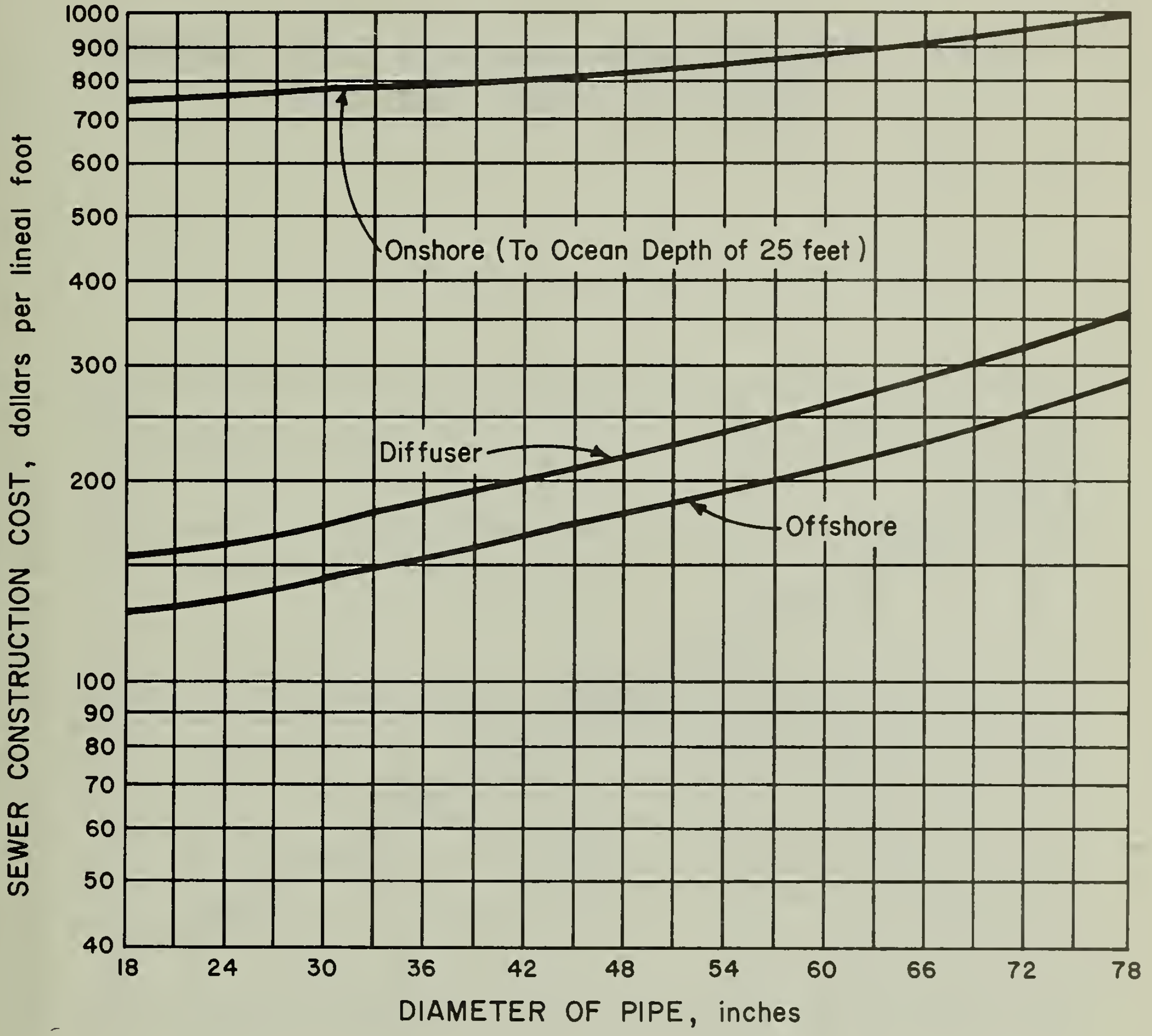
FIGURE VII-3

CONSTRUCTION COSTS DISSOLVED AIR FLOTATION FACILITIES FOR COMBINED SEWER OVERFLOWS



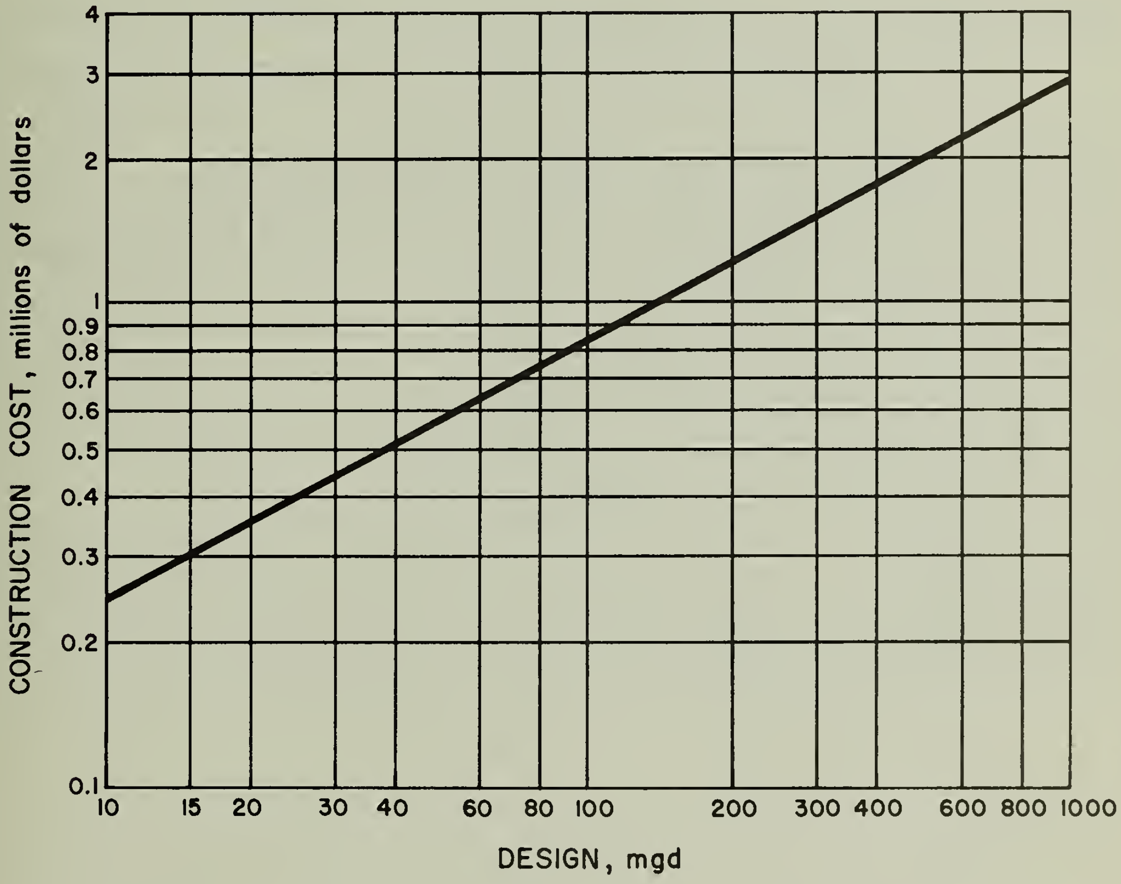
Costs are based on first class construction with architectural treatment to blend with environment. Costs do not include influent or effluent pumping stations. Costs do not include the cost of land or right-of-way nor do they include special foundation work such as piles or site dewatering. Costs do not include sludge processing or disposal facilities. Costs shown are based on an ENR construction cost index of 1,470 and include engineering and inspection costs.

OCEAN OUTFALL SEWER CONSTRUCTION COST



Costs are based upon the use of "DRG" (double rubber gasket) reinforced concrete pipe (bell and spigot) for the outfall section. Unit costs for the diffuser section are based upon the use of cast iron pipe for 24 inch pipe size and under, and upon the use of "DRG" concrete pipe with cast iron lateral diffusers as required for pipe size 30 inch and over. Unit costs include pipe, rock cradling, laying and inspection, as well as contractors overhead and profit. Costs shown for the offshore section reflect construction cost for pipe in water depths under 100 feet. Unit costs shown include the cost of engineering and administrative costs. The costs are adjusted to an ENR construction cost index of 1,470.

SEWAGE PUMP STATIONS CONSTRUCTION COSTS
MAXIMUM HEAD 125 FEET



Costs are based upon an ENR construction cost index of 1,470, and include engineering, inspection, and contractors profit. Costs do not include the cost of land nor do they include special foundation work such as piles or site dewatering.

CHAPTER VIII

REFERENCES

1. *"Characterization and Treatment of Combined Sewer Overflows"*, Engineering-Science, Inc., November 1967.
2. *"Report on Water Pollution Control Plants"*, Brown and Caldwell, 15 December 1970.
3. *"Marine Sewage Disposal System for Rio de Janeiro"*, Engineering-Science, Inc., June 1969.
4. *"Technical Objectives for Field Demonstration of Baker Street Outfall Dissolved Air Flotation Facility"*, Engineering-Science, Inc., November 1970.
5. Summary of Treatment Plant Operations - 1969-1970.
6. Summary of Treatment Plant Operations - 1968-1969.

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APPENDIX F

DISSOLVED AIR FLOTATION

CHARACTERIZATION OF THE RECEIVING WATER AND BEACH INTERTIDAL ZONE ENVIRONMENT

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DISSOLVED AIR FLOTATION

APPENDIX F

CHARACTERIZATION OF THE RECEIVING WATER AND BEACH INTERTIDAL ZONE ENVIRONMENT

Part of City and County of San Francisco's
Master Plan Study for Wet Weather Control Program

submitted by

City and County of San Francisco, California

prepared by

Engineering-Science, Inc.
Research and Development Laboratory/Berkeley

for

Environmental Protection Agency
Water Quality Office

July 1971

FOREWORD

This volume constitutes the sixth of seven technical appendices to the Project Report on Treatment of Combined Sewer Overflows by the Dissolved Air Flotation Process. Appendices in this series are:

A. Phase I - Pre-Construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach

B. Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility

C. Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process - A Pilot Plant Study

D. Design Factors for Baker Street Dissolved Air Flotation Facility

E. Costs for Dissolved Air Flotation Facilities

F. Characterization of the Receiving Water and Beach Intertidal Zone Environment

G. Performance Evaluation of Baker Street Facility with Raw Sewage

Appendix F is submitted in partial fulfillment of DPW Order No. 80,480 between the City and County of San Francisco and Engineering-Science, Inc., and was supported in part by Grant WPRD-258-01-68 between the Environmental Protection Agency, Water Quality Office, and the City and County of San Francisco, Department of Public Works.

This report, prepared in limited edition for utilization in City and County of San Francisco's Master Plan study for wet-weather control, is under review for approval by the Environmental Protection Agency, Water Quality Office.

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CHAPTER I

INTRODUCTION

BACKGROUND

The evaluation of the impact of the Baker Street dissolved air flotation facility on receiving water quality, as delineated in the original demonstration grant, is a vital consideration in the final operational evaluation of the dissolved air flotation process. Reference information for the characterization of receiving waters and the beach intertidal zones contiguous to Baker Street previous to the construction of the facility is presented in detail in Appendix A, *Phase I-Pre-construction Studies on Quantity and Quality Relationships of Combined Sewage Treatment and Receiving Water Studies at Outer Marina Beach*. Briefly, the findings of the pre-construction study provided considerable insight to the quality and hydrodynamic characteristics of the receiving waters contiguous to Baker Street, the impact of dry and wet weather, and a correlation between receiving water and beach intertidal zone quality. Measurements designed for a further elucidation of the receiving waters and littoral zone near Baker Street were utilized in the postconstruction monitoring program, the results of which are presented in this report.

INFORMATION NEEDS

Prerequisite to an evaluation of the effects on the receiving water of the treatment of wastewater flows by dissolved air flotation are the following:

(1) Specifications of the desired quality of the receiving waters contiguous to Baker Street.

(2) Characterization of the flow being introduced into the receiving waters by the dissolved air flotation facility.

(3) Dispersion capacity of the receiving waters in terms of providing wastewater dilution through a combination of initial and transport dilution processes.

To satisfy these needs within the constraints of the post-evaluation study, the available technical data were reviewed and supplemented, when possible, with field investigation.

RECEIVING WATER AND INTERTIDAL ZONE QUALITY OBJECTIVES

There are a series of subordinate objectives to the ultimate study objective, which is the evaluation of the effects of the dissolved air flotation process. The California Water Quality Control Board, San Francisco Region, has specified its perceived water quality and intertidal zone standards in its set of requirements which are listed in detail in Tables I-I and I-2. The bases for the requirements established by the Regional Water Quality Control Board were the fulfillment of the objectives of (I) the protection of the public health, (2) the protection of beneficial uses made of the receiving waters and adjacent intertidal areas, and (3) the protection of nuisance conditions. Of the set of requirements, four are quantitative in nature:

(I) The discharge shall not cause the pH of the receiving waters to be less than 7.0 nor greater than 8.5.

(2) The discharge shall not cause the concentration of dissolved oxygen to be less than 5.0 mg/l.

(3) The discharge shall not cause the concentration of dissolved sulfide to be greater than 0.1 mg/l.

(4) The receiving waters shall not have a coliform most probable number (MPN) greater than 10,000/100 ml as a result of the discharge in any single sample, or greater than 240/100 ml as a median of five consecutive samples.

The coliform requirement is the most stringent of the quantitative standards listed, and traditionally has been the focus of coastal water quality management problems in California.

There are, in addition to the requirements of the Regional Water Quality Control Board, objectives established by experience with comparable estuarine areas, such as the Los Angeles Harbor and Jamacia Bay, New York. These areas, like San Francisco Bay, serve as receiving waters

for substantial quantities of domestic wastewater and storm water runoff. The assimilative capacities of these waters are dependent upon, among other factors, dilution characteristics, which are constrained by various hydrodynamic conditions such as tidal, wind and current patterns.

CONDUCT

The receiving environment characterization studies were conducted prior to and in sequence with the prototype operation of the dissolved air flotation facility at Baker Street. Background information was obtained from receiving environment surveys conducted between December 1970 and March 1971, and performance evaluation studies were conducted in June 1971.

ORGANIZATION

The characterization program was performed by the staff of the Research and Development Laboratory/Berkeley, Engineering-Science, Inc., under the direction of Dr. William E. Gates. Dr. T.G. Shea served as Project Manager. Project staff included Dr. G.D. Beers, T.V. Wistrom, J.R. Bartlett, D.A. Cobb, and J.W. Price.

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TABLE I-1

WASTE DISCHARGE REQUIREMENTS OF THE CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO REGION, FOR WATERS RECEIVING WET WEATHER FLOWS FROM THE NORTH POINT SEWERAGE ZONE (RESOLUTION NO. 70-2)

The treatment or disposal of waste shall not create a nuisance as defined in Section 13050 (m) of the California Water Code.

None of the discharges shall:

Unreasonably affect any of the protected beneficial water uses resulting from:

Floating, suspended, or deposited macroscopic particulate matter, foam, oil, or grease in waters of the State at any place; floating oil shall be considered present if in enough quantity to cause iridescence;

Bottom deposits at any place;

Aquatic Growths at any place;

Color or turbidity;

More than 400 feet from discharges Nos. 9, 10, 11, 12, 13-14, 16, 17, 18, 19, 20 and 21, or beyond the mouth of China Basin Channel.

Cause waters of the State to exceed the following limits of quality at any place within one foot of the water surface:

pH	7.0	minimum
	8.5	maximum
Dissolved oxygen	5.0 mg/l	minimum
Dissolved sulfide	0.1 mg/l	maximum
Nutrients	to be prescribed at the earliest practicable date	

TABLE I-1 (Con't)

Other substances	any one or more substances in concentrations that impair any of the protected beneficial water uses or make aquatic life or wildlife unfit or unpalatable for consumption
Bacterial concentrations	in excess of a median value of 240 MPN coliform per 100 ml, as determined in any five consecutive samples collected at any one station, or any single sample to exceed an MPN coliform concentration of 10,000/100 ml at any time. Whenever either of these bacterial values is exceeded in the receiving water for any reason they shall both be met instead in the waste at some point in the treatment process, provided that at least one sample is collected from the initial portion of waste discharged during a storm. The discharger may demonstrate compliance in the waste stream as an optional alternative. The Board will accept proof of effective effluent disinfection in terms of factors other than bacterial concentrations if the discharger documents a sound statistical correlation between such factors and bacterial analysis, and provided the conditions of sewage strength and treatment do not change from the demonstration period.

TABLE I-2

WASTE DISCHARGE REQUIREMENTS OF THE CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO REGION, FOR WATERS RECEIVING DRY-WEATHER FLOWS FROM THE NORTH POINT SEWAGE TREATMENT PLANT (RESOLUTION NO. 70-17)

The treatment or disposal of waste shall not create a nuisance as defined in Section 13050(m) of the California Water Code.

The discharge shall not:

Unreasonably affect any of the protected beneficial water uses resulting from:

Floating, suspended, or deposited macroscopic particulate matter, or foam in waters of the State at any place;

Bottom deposits at any place;

Aquatic growths at any place;

Alteration of temperature, turbidity or apparent color beyond present natural background levels in waters of the State at any place.

Cause visible, floating, suspended or deposited oil or other products of petroleum origin in waters of the State at any place.

Waters of the State to exceed the following limit of quality at any place within one foot of the surface at any time:

Dissolved oxygen	5.0 mg/l minimum
Dissolved Sulfides	0.1 mg/l maximum
pH	7.0 minimum 8.5 maximum
Coliform Organisms	240 MPN/100 ml, median of five consecutive samples, maximum 10,000 MPN/100 ml, any single sample, maximum Whenever either of these bacterial values is exceeded in the receiving water for any reason they shall both be met instead in the waste at some point in the treatment process.

TABLE I-2 (Cont'd)

	The discharger may demonstrate compliance in the waste stream as an optional alternative. The Board will accept proof of effective effluent disinfection in terms of factors other than bacterial concentrations if the discharger documents a sound statistical correlation between such factors and bacterial analysis, and provided the conditions of sewage strength and treatment do not change from the demonstration period.
Nutrients	to be prescribed at the earliest practicable date.
Other substances	any one or more substances in concentrations that impair any of the protected beneficial water uses or make aquatic life or wildlife unfit or unpalatable for consumption.

CHAPTER II

SUMMARY

A consideration of the environmental quality of the receiving waters, sediments, and beach zones adjacent to the Baker Street dissolved air flotation facility is presented in this report. With the pre-construction receiving water studies as background and the evaluation of the effect of the dissolved air flotation facility on the receiving waters as an objective, a program for the acquisition of needed information is presented. The acquired information focused on a description of the hydrodynamics in the immediate vicinity of the discharge, the measurement and evaluation of water quality during wet weather and dry weather periods, and a description of nearshore and intertidal sediments. Receiving water quality relative to the standards established by the San Francisco Region of the California Regional Water Quality Control Board, as well as a discussion of desired environmental quality are presented.

CHAPTER III

INFORMATION ACQUISITION

PROGRAM

The three activity areas considered in the postconstruction phase of the characterization program were:

(1) Supplementation of the Phase I information on receiving water hydrodynamics.

(2) A background evaluation of the receiving waters and intertidal zones immediately prior to the operation of the dissolved air flotation facility at Baker Street.

(3) An operational evaluation of the effects of the dissolved air flotation facility on the quality of the receiving waters and intertidal zones.

METEOROLOGICAL INFORMATION

Hourly wind velocity measurements for the one-year period from 18 February 1970 to 17 February 1971 were obtained from the U. S. Army weather information facility at Chrissy Air Field in San Francisco. In addition, a series of on-site wind velocity measurements were conducted by Engineering-Science, Inc. during storm periods for 18 rainy periods, for five "rain-plus-one-day", and for four "rain-plus-two-days" periods.

HYDROLOGIC INFORMATION

Because currents play a predominant role in the consideration of wastewater dispersion in receiving waters the currents in the study area were characterized, at first with the use of floats and attached drogues, and secondly with markers. Information on water mass characteristics in the study area was obtained in an oceanographic monitoring program consisting of current velocity, salinity, temperature, and transparency determinations taken at two-hour intervals throughout a complete tidal cycle on 26-27 February 1971. Four sampling stations within a 1000-ft radius of the Baker Street outfall terminus were utilized in the series of measurements and are described in Table III-1.

TABLE III-I

DESCRIPTION OF SAMPLING STATIONS

RECEIVING WATER HYDROLOGICAL STUDIES, 26-27 FEBRUARY 1971

Station	Location
1	1,000 ft westerly of the outfall terminus and 300 ft offshore
2	At the outfall terminus
3	1,000 ft easterly of Station 2 and 300 ft offshore
4	700 ft northwesterly of Station 2

BACKGROUND EVALUATION STUDIES

An updated background evaluation of the receiving waters was comprised of a series of three coordinated monitoring surveys conducted under the conditions of dry weather at ebb tide, dry weather at flood tide, and wet weather at flood tide. The respective surveys were conducted on 10 December 1970, 3 February 1971, and 12 March 1971.

The 12 stations selected for sampling correspond to those of the Phase I receiving water studies, and are shown in Figure III-1. Seven stations (Nos. 1 through 7) are located approximately 250 ft offshore, and Station 1 is approximately 250 feet offshore on alignment of the former Baker Street outfall. A second line of stations (Nos. 9 through 11) are positioned approximately 1,500 ft offshore. A single station (No. 8) is positioned between the two lines of stations approximately 600 feet offshore on the former outfall alignment. Station No. 12, located south of Alcatraz Island, is the same as Station CB-5 of the University of California Comprehensive Study (1964) and was sampled to permit a comparison between present and recent historical water quality in the estuary (Reference 1).

Surface water samples were collected at a depth of three feet and subsurface samples three feet from the bottom. Samples from all 12 stations were analyzed for temperature, microplankton, chlorosity, and colifrom (total and fecal) organisms. Water transparency readings were also made at these locations.

Trawl net sampling of floatable materials was conducted between Stations 1 and 2 and Stations 1 and 3 westerly, and Stations 1 and 7 easterly of the existing outfall alignment,

The background evaluation of sediment quality was based on a set of samples collected from five of the offshore stations (Nos. 1, 2, 4, 5, and 12) and from six intertidal beach stations located along the Outer Marina Beach-Chrissy Air Field Beach sector as shown in Figure III-1 Station 2B is located at the foot of the Baker Street outfall. Stations 1B and 3B were 10 feet to the east and 120 feet to the west, respectively, of Station 2B. Station 4B, 5B, and 6B were 1,100, 4,600, and 6,000 feet west of Station 2B. Sediments from offshore stations were analyzed for

benthic animals, particle-size distributions, hexane extractable materials (HEM), total nitrogen, and total sulfide. Sediments sampled from the onshore locations were analyzed for hexane extractable materials.

DISSOLVED AIR FLOTATION EVALUATION STUDIES

Two activity areas were of concern in the operational evaluation of the dissolved air flotation facility:

(1) A preliminary dye study to assist in the determination of the approximate location of the effluent dispersion field at high and low slack tides, and to provide a quantitative description of the effluent dispersion characteristics in the receiving waters.

(2) Receiving water monitoring surveys under the conditions

(a) at low slack and the following flood tide, and

(b) at high slack and the following ebb tide.

Samples were taken along the observed effluent field and at the 12 routine sampling stations depicted in Figure III-1. Sampling stations within the effluent field were positioned at 500-ft intervals along the center line of the observed field; actual locations are represented in Figure III-1. In addition to monitoring fluorescent dye and coliform concentrations in the effluent field, measurements designed to complement the background evaluation studies were incorporated into the analytical program.

Receiving water surveys were conducted on 14 June 1971 and on 21 June 1971. A description of the tidal and Baker Street dissolved air flotation facility discharge conditions at the time of the surveys is presented in Table III-2.

METHOD OF SAMPLE COLLECTION AND ANALYSIS

The analytical program for receiving water and beach intertidal zone studies is shown in Table III-3. A boat was used for sampling of the offshore stations. Surface and subsurface waters were sampled with a Van Dorn sampler. Temperature measurements of the water were made on-deck.

TABLE III-2

DESCRIPTION OF TIDAL AND DISSOLVED AIR FLOTATION PLANT DISCHARGE CONDITIONS 14 AND 21 JUNE 1971

Date	Tidal Conditions		Plant Discharge Conditions				
	Time of		Time of		Total Time, hrs	Flow	
	Low Slack	High Slack	Start	Stop		mgd	gal
14 June 1971[1]	1139	1712	1255	2054	7.98	1.3	430,000
21 June 1971[2]	1851	1206	0957	2005	10.13	1.4	590,000

[1] Samples taken at approximately 1600 hours.

[2] Samples taken at approximately 1400 hours.

TABLE III-3

ANALYTICAL PROGRAM FOR RECEIVING WATER AND BEACH INTERTIDAL ZONE EVALUATION STUDIES

Type of Sample	Analysis	Method	Reference
Benthic	Total nitrogen	*Standard Methods*	1, 2
	Total sulfide	Titration	1
	Particle-size distribution	Hydrometer	1
	Hexane extractible material	Liquid-liquid extraction	1
	Benthic animals: species distribution and number	Standard counting	2
Water Column	Coliforms: total	Confirmed MPN	2
	Coliforms: fecal	44-45° MPN	2
	Floatables	Gravimetric	5, 6
	Chlorosity		2
	Microplankton: species distribution and number	Standard counting	2
Beach Intertidal Zone	Particle-size distribution	Standard sieves	
	Hexane extractible material	Liquid-liquid extraction	1
	Floatables	Gravimetric	5

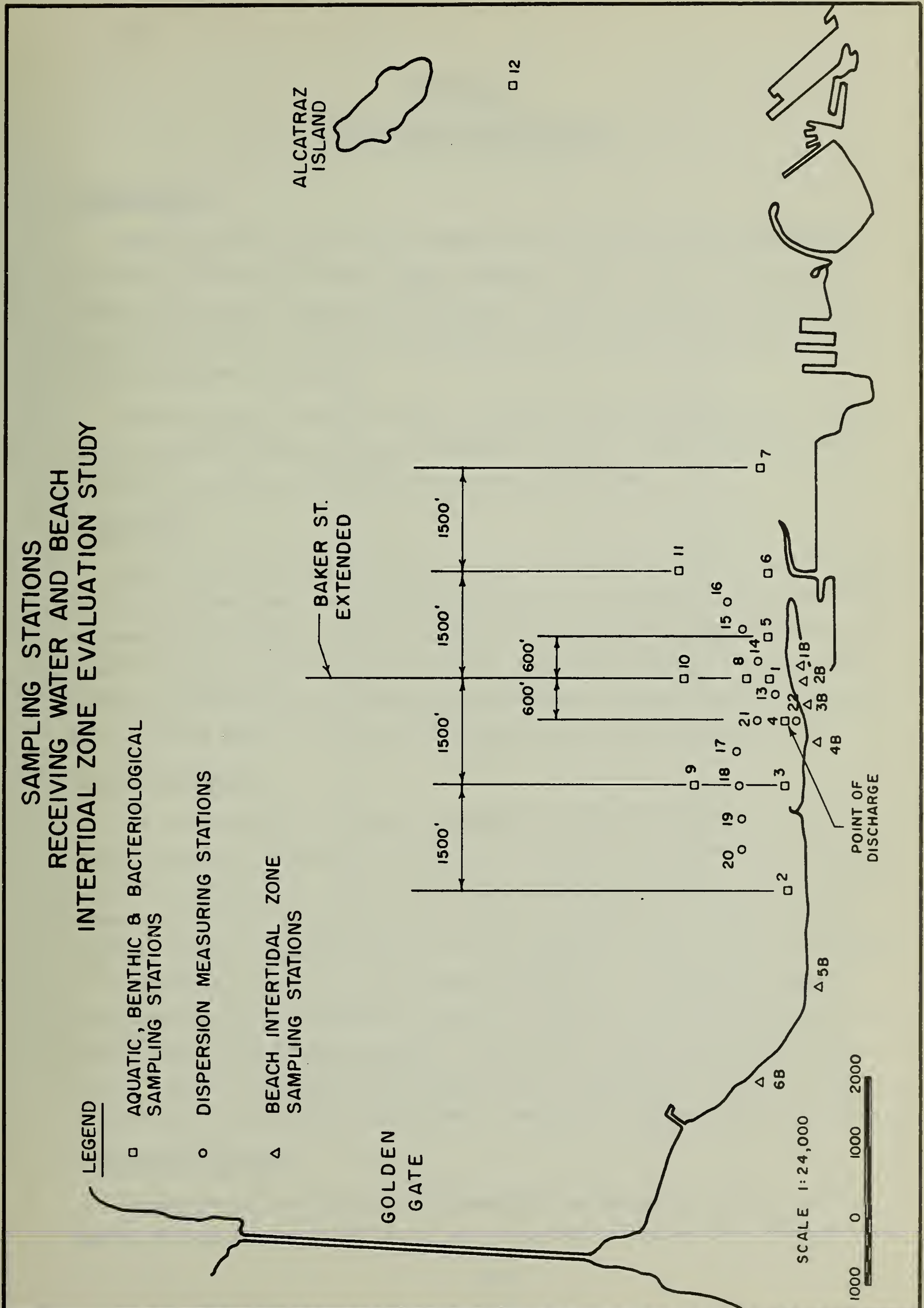
Transparency determinations were conducted by lowering a Secchi disc to the limit of visibility. Water samples for coliform analyses were collected in sterilized bottles and analyzed in accordance with the mulitple tube fermentation method (Reference 2). A portion of the sample was set aside for chlorosity analysis (Reference 3). A one-liter aliquot was withdrawn from the sample volume and preserved for microplankton analysis with a dilute solution of rose bengal dye and formalin solution. These organisms were counted and identified under a high-power microscope.

The floatables sampler (Appendix H of Appendix A, ***Phase 1 - Pre-Construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach***) was utilized to obtain samples for particulate and film (hexane extractable materials) analysis. Particulate materials were categorized and the amounts in the various categories determined. The hexane extractable materials analysis (Reference 1) was performed on the particulate floatable materials.

The sediments were sampled with a Peterson dredge. A portion of the sediment was preserved with zinc acetate for total sulfide analysis (Reference 1). A second portion was preserved with dilute acid solution for the total nitrogen analysis (Reference 2). A third portion of the sediment sample was bottled for particle-size distribution analysis (Reference 1) and determination of hexane extractable materials (Reference 1). A second dredge sample was collected and preserved with rose bengal dye-formalin solution. In the laboratory the sediments were separated for the biota and the biota classified to species.

The beach sediments form the intertidal zone were collected with a sled sampler device (Reference 4). The particle-size and HEM analyses were performed on the collected samples as prescribed in References 1 and 2.

FIGURE III -1



SAMPLING STATIONS
RECEIVING WATER AND BEACH
INTERTIDAL ZONE EVALUATION STUDY

ENGINEERING-SCIENCE, INC.

CHAPTER IV

INFORMATION PRESENTATION

HYDRODYNAMICS

The San Francisco Bay is an extensive estuarine system encompassing an area of 340 square miles. Water movements result from tidal exchange through the one-mile opening to the Pacific Ocean provided by the Golden Gate Straits, river inflow, wind-induced currents, and interaction with an irregular bottom topography.

The study area lies less than 1.5 miles from the Golden Gate. Currents result primarily from the direct exchange of waters from the Bay entrance, and also from river outflow and from prevailing winds.

Tidal Regime

Two high and two low tides occur every 24.75 hours with a vertical rise of five to seven feet, and are characteristic of the Pacific Coast Shelf and are manifest throughout the San Francisco Bay. Water movements within the study area are in sequence with those of the Golden Gate, with high slack occurring approximately 1.5 hours after maximum flood at the Bay entrance, and low slack about 2.75 hours after maximum ebb out the Golden Gate.

Current Patterns

Vector analyses on current measurements taken throughout a complete tidal cycle are presented in Figures IV-1 through IV-6. The data supports and further describes that of the Phase I study (Appendix A). Specifically, waters west of the site of the Saint Francis Yacht Club to approximately 1,000-ft offshore demonstrated little net movement, most of which occurred in the upper five feet, in an offshore direction. In contrast, waters approximately 250-ft offshore and east of the Saint Francis Yacht Club demonstrated considerable movement, 0.59 knots, towards the Golden Gate. Waters 1,000-ft offshore of the Baker Street dissolved air facility also demonstrated considerable net movement towards the Golden Gate (0.68 knots).

Water Mass Character

Temperature, salinity, and transparency measurements made at various depths throughout one tidal cycle are presented in Tables IV-1 through IV-4.

TABLE IV-1

CHARACTERIZATION OF RECEIVING WATER DURING A TIDAL CYCLE (STATION 1)

Date (1971)	Time of Day	Depth (ft)	Water Movement		Temperature (°C)	Salinity (ppt)	Transparency (%)
			Direction (°mag)	Speed (cm/sec)			
26 Feb	1230	1	315	6	9.6	30.7	20.0
		5	330	13	9.6	30.8	7.5
		10	280	5	9.3	31.1	10.0
		20	350	1	9.2	31.4	14.0
		30	275	1	9.4	31.3	15.0
	1430	1	375	35	9.4	31.3	7.5
		5	315	5	9.4	31.3	9.5
		10	315	3	9.2	31.4	10.5
		20	305	9	9.2	31.5	8.5
		30	300	11	9.2	31.6	9.0
	1555	1	240	41	9.4	30.8	2.5
		5	240	14	9.4	30.8	3.5
		10	240	7	9.4	30.8	2.5
		20	255	1	9.4	31.0	4.5
		25	270	1	9.4	31.0	4.5
	2100	1	75	33	9.5	27.6	4.0
		5	75	6	9.5	28.2	4.5
		10	80	19	9.6	28.4	3.5
		20	80	1	9.6	29.1	4.0
		25	75	3	9.5	29.3	3.5
	2210	1	40	2	9.5	29.0	9.5
		5	75	2	9.4	29.5	11.0
		10	105	1	9.4	29.6	12.5
		20	120	4	9.4	29.8	12.5
		25	75	2	9.4	30.2	11.0
	2400	1	35	9	9.2	30.0	13.0
		5	45	3	9.2	30.8	7.0
		10	135	2	9.2	30.8	9.0
		20	170	1	9.1	30.8	9.5
		30	170	3	9.1	31.1	9.0

TABLE IV-2

CHARACTERIZATION OF RECEIVING WATERS DURING A TIDAL CYCLE (STATION 2)

Date (1971)	Time of Day	Depth (ft)	Water Movement		Temperature (°C)	Salinity (ppt)	Transparency (%)
			Direction (°mag)	Speed (cm/sec)			
26 Feb	1310	1	270	6	9.6	30.6	10.5
		5	255	7	9.7	31.2	7.0
		10	265	2	9.5	31.3	3.0
		20	260	1	9.3	31.4	10.0
		30	295	10	9.3	31.5	11.5
	1450	1	340	10	9.4	31.2	10.5
		5	335	9	9.4	31.2	11.4
		10	140	3	9.4	31.3	9.5
		20	60	0	9.3	31.3	11.0
		25	360	1	9.3	31.3	11.0
	1610	1	225	2	9.5	31.4	8.0
		5	330	7	9.5	30.8	11.0
		10	190	4	9.5	30.7	10.0
		18	190	1	9.5	30.6	10.0
	2030	1	70	11	9.5	27.3	1.0
		5	210	1	9.6	27.7	2.0
		10	220	1	9.5	27.9	1.5
		18	225	1	9.7	28.0	2.0
		21	75	2	9.7	28.0	2.0
	2220	1	90	8	9.4	28.9	11.5
		5	85	1	9.4	29.7	11.5
		10	*	*	9.4	29.9	11.0
		20	*	*	9.3	29.9	11.0
27 Feb	0015	1	185	1	9.1	30.8	8.5
		5	175	1	9.1	30.9	8.5
		10	95	5	9.2	31.1	9.0
		20	335	2	9.2	31.0	9.0

*Instrument malfunction.

TABLE IV-3

CHARACTERIZATION OF RECEIVING WATERS DURING A TIDAL CYCLE (STATION 3)

Date (1971)	Time of Day	Depth (ft)	Water Movement		Temperature (°C)	Salinity (ppt)	Transparency (%)
			Direction (°mag)	Speed (cm/sec)			
26 Feb	1330	1	305	23	9.6	30.7	10.0
		5	285	75	9.5	31.1	11.5
		10	280	65	9.4	31.2	10.0
		20	275	53	9.3	31.3	4.5
		30	270	27	9.4	31.5	1.0
		35	260	8	9.3	31.4	4.5
	1510	1	285	86	9.5	30.4	7.0
		5	250	9	9.4	31.0	12.0
		10	260	15	9.4	31.0	7.5
		20	275	12	9.4	31.0	1.0
		30	275	10	9.3	31.1	3.0
		35	285	5	9.4	31.2	-
	1625	1	315	56	9.5	30.1	13.0
		5	300	12	9.5	30.0	9.5
		10	285	12	9.6	30.1	9.5
		20	270	7	9.5	30.0	11.0
		30	265	6	9.5	30.0	10.0
		35	345	9	9.5	30.0	10.0
	2015	1	250	24	9.7	26.5	3.0
		5	225	2	9.7	26.7	1.0
		10	215	9	9.7	27.0	1.0
		20	210	7	9.7	26.9	3.0
		30	190	2	9.6	27.0	3.0
		32	200	1	9.8	27.1	4.0
	2235	1	85	27	9.3	29.8	14.5
		5	85	10	9.4	29.7	12.5
		10	100	5	9.4	29.8	12.5
		20	100	9	9.4	29.9	12.5
		30	100	4	9.4	30.1	12.5
		35	100	1	9.3	30.2	12.5
27 Feb	0030	1	90	7	9.2	30.6	9.5
		5	70	1	9.2	30.7	9.0
		10	60	1	9.3	30.8	9.0
		20	160	1	9.1	31.1	9.0
		30	200	3	9.2	31.2	9.0
		35	345	1	9.2	31.2	9.5

TABLE IV-4

CHARACTERIZATION OF RECEIVING WATERS DURING A TIDAL CYCLE (STATION 4)

Date (1971)	Time of Day	Depth (ft)	Water Movement		Temperature (°C)	Salinity (ppt)	Transparency (%)
			Direction (°mag)	Speed (cm/sec)			
26 Feb	1410	1	325	67	9.6	30.6	20.0
		5	295	14	9.5	30.8	12.0
		10	305	19	9.5	30.8	15.0
		20	315	-	9.4	30.9	14.0
		30	210	48	9.3	30.9	12.0
		40	305	36	9.2	31.7	11.0
	1535	1	265	93	9.5	30.4	4.0
		5	260	29	9.5	30.3	3.5
		10	265	27	9.4	30.6	4.0
		20	265	27	9.4	30.6	3.0
		30	260	30	9.3	30.8	1.5
		40	260	25	9.3	31.1	2.5
	1640	1	305	17	9.7	28.8	6.5
		5	300	12	9.7	28.9	6.5
		10	295	16	9.7	29.0	5.0
		20	300	14	9.6	29.3	5.5
		30	300	-	9.5	29.6	5.5
		40	295	33	9.5	29.7	6.0
	2120	1	65	6	9.6	28.4	4.0
		5	70	1	9.6	28.6	7.5
		10	70	17	9.5	28.7	6.0
		20	70	23	9.5	28.9	6.0
		30	70	9	9.6	29.2	4.0
		40	70	20	9.6	29.5	2.0
	2300	1	75	9	9.3	30.2	8.0
		5	75	7	9.4	30.1	10.0
		10	100	4	9.3	30.3	10.0
		20	110	6	9.3	30.4	10.0
		30	110	17	9.2	30.6	10.0
		40	115	10	9.2	30.8	10.0
27 Feb	0050	1	35	7	9.0	30.6	12.0
		5	20	2	9.1	31.0	8.0
		10	20	1	9.2	31.1	8.0
		20	105	1	9.1	31.0	8.0
		30	150	1	8.9	31.7	7.5
		40	150	4	9.0	31.8	8.0

For the purpose of tracking individual water masses, temperature-salinity diagrams were prepared for each of the six sampling periods encompassing one tidal cycle. The diagrams provide the identification of like water masses as well as an indication of the stability of particular water masses, and are presented in Figures IV-7 through IV-9.

Presented in Figure IV-1 are indications that at full ebb tide more stratification exists at Stations 3 and 4 than at Stations 1 and 2. At ebb tide, the waters at Stations 3 and 4 were similar and of relatively high density, indicating a possible origin from the South Bay; the water masses at Stations 3 and 4 were not the same, however. Between the surface and a depth of 35 feet, the waters at Stations 1 and 2 are identical and can be characterized by a relatively high estuarine salinity of 30.7 to 31.5 ppt, also with South Bay as the probable origin.

Following the full ebb tide, surface salinities demonstrated a decrease at all stations, reaching low levels of 26.5 ppt at Station 3 and 28.4 ppt at Station 4 at low slack. Considerable stratification was evident at low slack at all of the four stations.

As flood tide developed, salinity and temperature levels increased, indicating an enroachment of ocean water through the Golden Gate. A maximum salinity of 31.8 ppt was reached at this time, as was a maximum degree of homogeneity. With the development of high slack, the stations appeared to assume the characteristics existing at full ebb tide.

WIND PATTERNS

Geographical location largely dictates the wind characteristics and the resultant effects on the water movement in the Study Area. The city of San Francisco serves as a partial barrier to the east, south, and, to some extent, to the west. Marin County, located four miles to the north, also provides an attenuating effect on the winds. In addition, Angel and Alcatraz Islands provide some protection from the buildup of waves. The physical location of the Study Area is such that winds from the west and north are the primary causes of the onshore movement of surface waters.

Seasonal wind patterns are presented in Figures IV-10 through IV-13. The spring months (March, April, and May) can be characterized as being

generally offshore and parallel to the Baker Street shoreline. Winds in the summer months (June, July, and August) are light and generally offshore. In the fall (September, October, and November) winds are again predominantly offshore, with occasional onshore breezes originating from the north. A trend toward increased northerly and northwesterly winds continue through the winter months (December, January, and February), in which case surface waters can be expected to be blown onshore.

Since the operation of the Baker Street dissolved air flotation facility is a function of storm water runoff, consideration was given to the characterization of winds during wet-weather condtions. Results of a series of wind measurements taken during rainy periods are presented in Figure IV-14 and are characterized as originating predominantly from the southeast and having a mean velocity of 6.3 knots. The southerly tendencies which prevail during rainy conditions, however, subside approximately one day after a storm as shown in Figures IV-15 and IV-16.

EFFLUENT DISPERSION PATTERNS

Concentrations of fluorescent dye tracer and coliform organisms observed in the dispersion field during the discharge from the Baker Street dissolved air flotation facility on 14 June 1971 and 21 June 1971 are presented in Table IV-5. During the 14 June 1971 survey, tide was flooding; and on the 21 June 1971 survey, it was ebbing. Dye concentrations near the bottom at all stations but one (outfall terminus) during both surveys were below the reliable precision of the fluorometer, namely 1.0 ppb. Similarly, many of the surface stations indicated concentrations of less than 1.0 ppb. Results from the second survey indicated that dye concentrations were diluted about 8-fold in rising from the outfall terminus to the surface. Initial dilution due to vertical rise on the survey of 14 June 1971 cannot be determined reliably due to the exceptionally high chlorine residual (33.5 mg/l) in the effluent which most likely caused an attenuation of concentration by chemical oxidation of the tracer dye. Measures of the dilution effected by horizontal dispersion at the surface are probably reliable, however, because the chlorine residual should have been sufficiently diluted in the rising plume to have little oxidative effect on the remaining fluorescent species.

TABLE IV-5

RECEIVING WATER COLIFORM AND DYE CONCENTRATIONS IN EFFLUENT FIELD FROM DISSOLVED AIR FLOTATION FACILITY

14 June 1971
Flood Tidal Conditions[1]

Station	Rhodamine WT Dye (ppb)[2]		Total Coliform (MPN/100 ml)[3]	
	Top	Bottom	Top	Bottom
1	2.0	<1.0	2.3×10^3	7
2	<1.0	<1.0	9	9.3×10
3	<1.0	<1.0	4	9
4	16.0	<1.0	1.1×10^5	6.2
5	1.5	<1.0	4.3×10^3	4
6	1.0	<1.0	4.3×10^2	<3
7	<1.0	<1.0	2.1×10	2.9×10
8	<1.0	<1.0	4.3×10^2	1.5×10
9	<1.0	<1.0	2.3×10	<3
10	<1.0	<1.0	1.1×10	1.5×10
11	<1.0	<1.0	7	9
12	<1.0	<1.0	4.3×10	7
13	7.0	<1.0	4.6×10^6	1.1×10^5
14	2.0	<1.0	$\geq 2.4 \times 10^7$	2.4×10^4
15	2.2	<1.0	2.4×10^2	1.5×10^4
16	<1.0	<1.0	4.6×10^4	$\geq 2.4 \times 10^7$

[1] Chlorine Residual in Effluent Line: 33.5 mg/l

[2] Dye Concentration in Outfall Line: 1,190 ppb

[3] Influent MPN/100 ml: 4.3×10^7
Effluent MPN/100 ml: <30

21 June 1971
Ebb Tidal Conditions[4]

Station	Rhodamine WT Dye (ppb)[5]		Total Coliform (MPN/100 ml)[6]	
	Top	Bottom	Top	Bottom
1	<1.0	<1.0	2.3×10	1.1×10^3
2	<1.0	<1.0	2.3×10^5	2.4×10^4
3	<1.0	<1.0	4.6×10^2	2.4×10^2
4	20.0	<2.0	$\geq 2.4 \times 10^7$	2.4×10^6
5	<1.0	<1.0	9.3×10	2.3×10
6	<1.0	<1.0	4.3×10	2.3×10
7	<1.0	<1.0	7.5×10	2.3×10
8	<1.0	<1.0	2.3×10	9.3×10
9	<1.0	<1.0	2.3×10	2.7×10
10	<1.0	<1.0	4.3×10	7.5×10
11	<1.0	<1.0	1.1×10^3	2.3×10
12	<1.0	<1.0	2.1×10	1.5×10
17	8.0	<1.0	4.6×10^6	1.1×10^5
18	<1.0	<1.0	$\geq 2.4 \times 10^7$	2.4×10^4
19	<1.0	<1.0	2.4×10^2	1.5×10^4
20	<1.0	<1.0	4.6×10^4	$\geq 2.4 \times 10^7$
21	3.0	<1.0	4.6×10^6	2.3×10^5
22	2.0	<1.0	4.6×10^6	9.3×10^5

[4] Chlorine Residual in Effluent Line: 0.5 mg/l

[5] Dye Concentration in Outfall Line: 152 ppb

[6] Influent MPN/100 ml: 4.6×10^8
Effluent MPN/100 ml: 2.1×10^4

Coliform densities observed during both surveys were quite variable, and not subjected to analysis for determination of the dispersion characteristics of the receiving waters.

Determinate values, based on dye concentrations, relating observed dilutions at surface stations to distance from the outfall terminus on the approximate centerline of the dispersing plume are presented in Figure IV-17. Although the data are not definitive, it would appear that greater dilutions occurred on the ebb tide of 21 June 1971 since the dilution observed within 700 feet of the outfall (Station 1) along the general centerline of the plume was greater than 20, as were dilutions at 1,000, 1,500, and 2,000 feet (Stations 18, 19, and 20, respectively).

WATER QUALITY

The parameters for the characterization of receiving water quality were based on (1) the standards established by the Regional Water Quality Control Board, and (2) the parameters used in the Phase I program. Reported herein are the results of the three surveys conducted in the postconstructional evaluation phase of the study.

Transparency

Two sets of Secchi disc readings were made in the receiving waters, and the results are presented in Table IV-6. Measurements varied from 4.0 to 5.0 feet, with a mean of 4.3 feet on 10 December 1970, during dry-weather conditions and an ebb tide. Corresponding measurements made on 3 February 1971 at flood tide produced a range of 2.5 to 4.5, with a mean of 3.4 feet.

Floatable Materials

Presented in Tables IV-7, IV-8, and IV-9 are summary descriptions of the floatable materials collected during dry-weather conditions at ebb and flood tidal stages on 11 December 1970 and on 3 February 1971. The mean dry-weather concentration of floatable materials for both easterly and westerly traverses was 43.9 mg/sq m at ebb tide and 1.1 mg/sq m at flood tide. The 40-fold difference may be a reflection of the water mass turnover resulting from fluctuations in the tidal cycle.

TABLE IV-6

RECEIVING WATER TRANSPARENCY

(feet)

Date	Station												Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
10 Dec 1970	4.0	4.5	4.5	4.5	4.0	4.5	4.5	4.0	5.0	4.0	4.0	4.5	4.3
3 Feb 1971	3.5	4.0	3.0	3.0	3.0	3.5	3.0	4.0	4.5	4.0	3.0	2.5	3.4

TABLE IV-7

COMPOSITION OF SAMPLES OF FLOATABLE MATERIALS

11 December 1970

Dry-Weather, Ebb Tide

Traverse*	Characteristics	HEM (mg/g)	Mass/Area (mg/sq m)
Sta. 1 → Sta. 2 (Tow A)	Vegetable material		0.02
	Animal material		0.00
Area: 556 sq m	Man-made material		2.69
	Total	439	2.71
Sta. 1 → Sta. 2 (Tow B)	Vegetable material		0.36
	Animal material		0.08
Area: 556 sq m	Man-made material		1.10
	Total	225	1.54
Sta. 7 → Sta. 1 (Tow A)	Vegetable material: primarily seaweed		127.7
	Animal material		8.7
Area: 556 sq m	Man-made material		32.1
	Total	99	168.5
Sta. 7 → Sta. 1 (Tow B)	Vegetable material		2.07
	Animal material		0.00
Area: 556 sq m	Man-made material		0.86
	Total	163	2.93

* Sampling time: 1315-1415.

Tides for 11 December 1970 (Golden Gate):

Time	Height (ft)
0312	2.9
0930	6.6
1648	-1.4
2354	4.6

TABLE IV-8

COMPOSITION OF SAMPLES OF FLOATABLE MATERIALS

3 February 1971

Dry Weather, Flood Tide

Traverse[1]	Characteristics	HEM (mg/g)	Mass/Area (mg/sq m)
Sta. 1 → Sta. 3	Vegetable material: predominantly straw		1.63
Area: 381 sq m	Animal material		0.04
	Man-made material: predominantly oil		0.42
	Total	215	2.09
Sta. 7 → Sta. 1[2]	Vegetable material		0.04
Area: 556 sq m	Animal material		0.01
	Man-made material: predominantly oil		0.01
	Total	200	0.06

[1] Sampling time: 1830-1930

Tides for 3 February 1971 (Golden Gate)

Time	Height (ft)
0518	6.0
1248	0.0
1948	3.8
2336	3.0

[2] The sampling net was covered with oil when retrieved on the boat deck. Apparently an oil slick was traversed during the sampling tow. The HEM value (approximately 30 g) for the oily material adhering to the net was not included in data listed in this table.

TABLE IV-9

COMPOSITION OF SAMPLES OF FLOATABLE MATERIALS

12 March 1971

Wet Weather, Flood Tide

Traverse[1]	Characteristics	HEM (mg/g)	Mass/Area (mg/sq m)
Sta 1 → Sta 7	Vegetable material: predominantly large pieces of wood, some straw and seaweed		474.0
Area: 556 sq m	Animal material: jelly fish, small shrimp.		7.1
	Man-made material		3.5
	Total	12.0	484.6[2]
Anita Rock → Sta 4	Vegetable material: straw, seaweed, twigs		15.0
Area: 336 sq m	Animal material: jelly fish, small shrimp		12.0
	Man-made material		11.4
	Total	74.0	38.4

1. Sampling time: 2256 - 2348

   Tides for 12 - 13 March 1971 (Golden Gate)

Time	Height (ft)
0530	1.3
1148	4.9
1742	0.8
0018	5.1

2. 31.0 mg/sq m not including the wood

Table IV-9 depicts the floatable materials collected during wet-weather conditions, with a mean concentration of 261.5 mg/sq m, a 238-fold increase over dry-weather during a corresponding tidal phase. Since the major portion of this value is the result of a single piece of wood, however, the meaning of the reflected value is subject to question.

The average composition of floatable materials was found to vary under different conditions, specifically in the concentration of man-made materials, which comprised an average of 54 percent of the total floatables on the ebb tide, and 20 percent of the total floatables on the flood tide.

Receiving water floatable samples were taken while the dissolved air flotation facility was in operation. The floatable materials collected at that time, under dry-weather conditions and at ebb tide, were roughly equivalent, quantitatively and qualitatively, to those formerly collected during flood tide and dry-weather conditions, as shown in Table IV-10.

At this point, it is difficult to predict the actual effect of the dissolved air flotation process on the character and levels of floatable materials in the receiving waters. However, since the removal of floatable materials is inherent in the wastewater treatment process, it is expected that the operation of the Baker Street facility would be reflected in lower levels of floatable materials in the receiving waters.

Coliform Organisms

Background Evaluation

The results of the analyses for the total and fecal coliform organisms are expressed in terms of the most probable number (MPN)/100 ml of sample and are presented in Table IV-11. There were no consistent differences between the samples taken three feet from the surface and one foot from the bottom as evidenced by the median total coliform levels, which were the same during both dry-weather and wet-weather surveys (240/100 ml and 1,100/100 ml, respectively).

For the purposes of comparison, the coliform data were analyzed by the same processes used in data analysis in Phase I (Appendix A, *Phase I - Pre-Construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach*). These

TABLE IV-10

COMPOSITION OF SAMPLES OF FLOATABLE MATERIALS DURING OPERATION OF DISSOLVED AIR FLOTATION FACILITY

21 June 1971

Dry Weather, Ebb Tide

Traverse[1]	Characteristics	HEM (mg/g)	Mass/Area (mg/sq m)
Sta 4 → Sta 2	Vegetable material		0.827
Area: 898m^2	Animal material: mostly copepods		
	Man-made material		0.058
	Total	66.9	0.885
Sta 7 → Sta 4	Vegetable material: primarily wood and fragments of brown algae		0.709
Area: 1330m^2	Animal material, mostly copepods		
	Man-made material		0.205
	Total	202	0.914

1. Sampling time: 1400-1502. Each traverse was made twice.

   Tides for 21 June 1971 (Golden Gate)

Time	Height (ft)
0524	-1.5
1230	4.5
1630	3.1
2248	6.6

2. By weight approximately 80 percent vegetable material and 20 percent animal material.

TABLE IV-11

COLIFORM CONCENTRATIONS

(MPN/100 ml)

3-FOOT DEPTH

Survey	Station											
	1	2	3	4	5	6	7	8	9	10	11	12
10 Dec 1970												
Total	240	120	93	93	93	1,100	240	240	240	240	240	93
Fecal	23	4	<3	<3	<3	11	<3	<3	23	43	9	3
3 Feb 1971												
Total	62	240	240	62	240	62	700	240	240	62	62	62
Fecal	<4.5	<4.5	<4.5	<4.5	<4.5	<4.5	6	<4.5	6	23	23	23
12 Mar 1971												
Total	1,100	4,600	1,100	1,100	2,400	2,400	2,400	1,100	1,100	460	460	2,400
Fecal	<3	15	1,100	240	2,400	43	210	210	460	93	460	<3

TABLE IV-11 (Cont'd)

1 FOOT FROM BOTTOM

Survey	Station											
	1	2	3	4	5	6	7	8	9	10	11	12
10 Dec 1970												
Total	460	240	240	240	240	93	240	240	240	240	240	-
Fecal	23	<3	<3	<3	<3	<3	<3	9	9	93	11	-
3 Feb 1971												
Total	240	62	62	23	240	62	240	240	62	62	62	62
Fecal	<4.5	<4.5	6	6	<4.5	<4.5	6	23	23	<4.5	23	6
12 Mar 1971												
Total	1,100	460	1,100	460	1,100	2,400	1,100	2,400	2,400	1,100	460	2,400
Fecal	<3	240	240	150	460	15	28	1,100	240	11	240	<3

procedures consisted of analyses to determine the statistical significance of differences in coliform MPN concentrations between observations made during rainy days and dry days, and during flood and ebb tides. The analyses consisted of determination by computer of the mean, standard deviation, and standard error of means among the sets of data. The significance of the difference among the sets of data was determined by the 180° overlap test with the standard error of the mean (Reference 7). Results are presented in Table IV-12.

The mean coliform MPN concentrations (for all current stages) varied from 0.58 log unit (Station 11) to 1.53 log unit (Station 12) greater during wet-weather conditions than the respective mean concentrations during dry-weather. That is, coliform MPN concentrations at these stations were from 4 to 34 times greater during wet-weather than during dry-weather. Of the 12 sampling locations, the mean coliform MPN concentration in wet-weather was 9 times greater (0.95 log unit) than in dry-weather. Thus, a significant increase in the coliform MPN concentrations in the receiving waters adjacent to the site of the Baker Street outfall can be expected with the onset of wet-weather conditions.

An analysis of the statistical characteristics of the coliform MPN data observed in the receiving waters of the Baker Street outfall during two tidal current stages on rainy days and on dry days is presented in Table IV-13. Where possible, the data were compared with the 180° overlap test, whereby the statistical significance of the distributions is assessed as a function of the degree of overlap of the standard error of means of the distributions (Reference 7). The results of the analysis show that a statistically significant difference exists between the distribution of coliform MPN observations for flood and for ebb stages at a 68 percent confidence level.

The magnitude of the difference between the ebb and flood stages of the tidal cycle is evidenced by the mean MPN concentrations at each stage, *i.e.*, flood was 154/100 ml, and ebb was 254/100 ml.

The mean coliform MPN concentration at ebb was found to be 1.7 times greater than during flood stages.

As a summary to the coliform analyses, the probable occurrence of

TABLE IV-12

BACKGROUND COLIFORM DATA SUMMARY FOR BAKER STREET RECEIVING WATERS

Weather and Tidal Currents	Station																	
	1			2			3			4			5			6		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Dry days, all currents	2.30	0.36	4	1.91	0.66	4	2.18	0.30	4	1.88	0.44	4	2.12	0.51	4	2.32	0.63	4
Rainy days, all currents	3.04	0.00	2	3.16	0.71	2	3.04	0.00	2	2.85	0.26	2	3.21	0.24	2	3.38	0.00	2
Dry days, ebb	2.57	0.26	2	3.16	0.71	2	3.04	0.00	2	2.85	0.26	2	3.21	0.24	2	3.38	0.00	2
Dry days, flood	2.08	0.28	2	2.08	0.28	2	2.08	0.28	2	1.08	0.34	2	2.38	0.00	2	1.79	0.00	2
Rainy days, flood	3.04	0.00	2	3.16	0.71	2	3.04	0.00	2	3.35	0.00	2	3.21	0.24	2	3.38	0.00	2

TABLE IV-12 (Cont'd)

Weather and Tidal Currents	Station																	
	7			8			9			10			11			12		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Dry days, all currents	2.50	0.24	4	2.38	0.00	4	2.24	0.29	4	2.08	0.26	4	2.08	0.26	4	1.85	0.10	3
Rainy days, all currents	3.21	0.24	2	3.21	0.24	2	3.21	0.24	2	2.85	0.27	2	2.66	0.00	2	3.38	0.00	2
Dry days, ebb	3.21	0.24	2	3.21	0.24	2	3.21	0.24	2	2.85	0.26	2	2.66	0.00	2	3.38	0.00	2
Dry days, flood	2.12	0.37	2	2.38	0.00	2	2.08	0.28	2	1.79	0.00	2	1.79	0.00	2	1.79	0.00	2
Rainy days, flood	3.21	0.24	2	3.21	0.24	2	3.21	0.24	2	2.85	0.27	2	2.66	0.00	2	3.38	0.00	2

NOTES: (1) $\bar{X}$ = mean log MPN/100 ml; S.D. = standard deviation; N = number of observations.

(2) All data from sampling program between 10 December 1970 and 12 March 1971.

(3) Dry days: 10 December 1970 and 3 February 1971.

(4) Rainy days: 12 March 1971.

TABLE IV-13

EFFECT OF TIDAL CURRENT STAGE ON COLIFORM MPN IN BAKER STREET RECEIVING WATERS

Tidal Current	$\bar{X}$ $\frac{\text{Log MPN}}{\text{100ml}}$	Range $\frac{\text{Log MPN}}{\text{100ml}}$	S.D. $\frac{\text{Log MPN}}{\text{100ml}}$	N	S.E. mean $\frac{\text{Log MPN}}{\text{100ml}}$	Significance @ 180° Overlap Test		
						Tide Stage	@ 1SE	@ 2SE
Flood	1.96	1.08-2.38	0.33	12	0.09	Ebb	Yes	Yes
Ebb	3.06	2.57-3.38	0.26	12	0.07	Flood	Yes	Yes

Notes: (1) S.E. mean = $\frac{SD}{\sqrt{N}}$ where: S.E. mean = standard error of mean; S.D. = standard deviation

(2) Significance at 1 S.E., 68 percent confidence; at 2 SE, 95 percent confidence

(3) 180° overlap test (Reference 7)

coliform concentrations during varying weather and tidal conditions is illustrated in Figure IV-18. Without the operation of the dissolved air flotation facility at Baker Street, a coliform MPN of 1,000/100 ml is likely to be reached or exceeded 96 percent of the time during wet-weather and flood tidal conditions, whereas, the probability is less than 1 percent during dry-weather at flood tide and less than 3 percent during dry weather at ebb tide.

Dissolved Air Flotation Evaluation

Coliform (total and fecal) concentrations observed during the two receiving water surveys conducted during the operation of the Baker Street dissolved air flotation facility are presented in Table IV-14.

Bacterial levels in the effluent field are expected to be dependent upon the extent of chlorination utilized in the treatment process, as was observed in the evaluation studies. On 14 June 1971, the dissolved air flotation facility was reported to have utilized extensive chlorination, and reported coliform levels were considerably lower than background dry-weather coliform levels. Less extensive chlorination was employed on 21 June 1971, and mean log coliform values reported for that date corresponded roughly to the background concentrations during dry-weather conditions. Comparisons are shown in Table IV-15.

Other Water Quality Measurements

Water temperature and chlorosity measurements taken during four receiving water surveys are presented in Table IV-16. Mean water temperatures were 12.9, 10.5, 9.8, and 12.2° C for the four respective surveys. A variation of 0.0 to 1.1°C was found to occur throughout the depth profile, with no consistent trend depicted.

Chlorosity values for the surveys fell within the normal range of 15 to 20 g/l for the study area (Reference 1). There were no spatial or temporal trends apparent in the data.

Listed in Table IV-17 are the results of microplankton analyses performed on samples collected on 10 December 1970. The concentration of microplankton ranged from 5,000 to 30,500 organisms/liter of water sample. At least eighteen varieties of organisms were represented, with a minimum

TABLE IV-14

COLIFORM CONCENTRATIONS IN BAKER STREET RECEIVING WATERS DURING OPERATION OF DISSOLVED AIR FLOTATION FACILITY

14 and 21 June 1971
(MPN/100 ml)

3-FOOT DEPTH

Survey	Station											
	1	2	3	4	5	6	7	8	9	10	11	12
14 June 1971												
Total	2,300	9	4	11×10^4	4,300	430	21	430	23	11	7	43
Fecal	430	<3	<3	93×10^2	2,300	150	<3	<3	<3	<3	<3	<3
21 June 1971												
Total	23	23×10^4	460	$\geq 24 \times 10^6$	93	43	75	23	23	43	1,100	21
Fecal	9	2,300	460	$\geq 24 \times 10^6$	23	43	43	23	23	15	11	<3

TABLE IV-14 (Cont'd)

1 FOOT FROM BOTTOM

Survey	Station											
	1	2	3	4	5	6	7	8	9	10	11	12
14 June 1971												
Total	7	93	9	6.2	4	<3	29	15	<3	15	9	7
Fecal	7	9	9	<3	4	<3	15	9	<3	15	<3	<3
21 June 1971												
Total	1,100	24×10^3	240	$\geq 24 \times 10^5$	23	23	23	93	27	75	23	15
Fecal	1,100	24×10^3	240	$\geq 24 \times 10^5$	23	23	23	93	27	75	23	9

TABLE IV-15

COLIFORM DATA SUMMARY FOR BAKER STREET RECEIVING WATERS PRIOR TO AND DURING OPERATION OF DISSOLVED AIR FLOTATION FACILITY

Date	Plant Discharge (gal)	Effluent Residual Cl_2 (mg/l)	Tidal Conditions	Mean Log MPN/100 ml		
				All Stations	Surface	Bottom
10 Dec 1970	None	-	Ebb	2.18	1.99	2.09
3 Feb 1971	None	-	Flood	2.00	2.12	1.87
14 June 1971	43,000	33.5	Flood	1.54	2.09	0.99
21 June 1971	62,300	0.5	Ebb	2.47	2.58	2.34

TABLE IV-16

WATER TEMPERATURE AND CHLOROSITY

Station		1		2		3		4		5		6	
Depth (ft)		40		20		30		50		40		45	
Sample Identification*		T	B	T	B	T	B	T	B	T	B	T	B
Measurement	Date												
Temperature (°C)	10 Dec 1970	12.8	12.8	13.0	13.0	13.0	13.0	13.0	13.0	12.8	12.8	12.8	12.8
	3 Feb 1971	11.0	11.0	10.3	10.8	10.9	10.7	10.2	11.0	10.5	10.9	9.5	10.6
	12 Mar 1971	9.8	9.8	9.8	9.8	9.8	9.8	9.8	10.0	9.8	9.8	10.0	10.0
	21 June 1971	12.3	12.4	12.0	11.8	12.1	11.9	12.2	12.1	12.5	12.2	12.5	12.2
Chlorosity (g/l)	10 Dec 1970	15.2	16.6	15.3	16.6	16.2	16.9	15.8	16.5	14.9	16.8	16.2	16.9
	3 Feb 1971	11.8	14.2	12.2	16.0	11.8	15.5	13.0	15.5	12.0	15.5	12.0	16.2
	12 Mar 1971	16.5	17.2	17.0	17.5	17.2	17.0	17.2	17.5	16.5	17.0	16.5	17.2
	21 June 1971	17.2	16.9	16.9	17.0	17.0	17.0	16.9	16.9	16.9	16.9	16.9	17.0

TABLE IV-16 (Cont'd)

Station		7		8		9		10		11		12	
Depth (ft)		25		55		55		55		60		120	
Sample Identification*		T	B	T	B	T	B	T	B	T	B	T	B
Measurement	Date												
Temperature (°C)	10 Dec 1970	12.8	12.8	13.0	13.0	13.0	12.8	13.0	13.0	13.0	13.0	13.0	-
	3 Feb 1971	10.2	10.5	10.5	11.0	10.5	10.8	10.5	9.7	10.3	10.3	10.5	10.5
	12 Mar 1971	10.0	9.8	10.0	9.8	9.8	9.8	9.6	9.8	9.8	9.8	10.2	10.0
	21 June 1971	12.5	12.3	12.2	12.1	12.6	12.0	12.5	12.3	12.5	12.3	14.7	12.8
Chlorosity (g/l)	10 Dec 1970	14.0	17.0	16.2	16.2	16.0	16.8	15.6	16.8	14.5	16.5	11.8	-
	3 Feb 1971	10.5	15.8	11.8	16.0	12.5	19.0	12.2	16.5	12.0	12.0	12.0	12.0
	12 Mar 1971	16.2	17.0	16.5	17.0	17.0	17.2	17.0	17.2	16.8	17.2	16.0	16.5
	21 June 1971	16.8	16.9	16.9	17.0	16.8	17.0	16.8	16.8	16.8	16.8	15.6	15.9

* T was 3 ft from surface; B was 1 ft from bottom.

TABLE IV-17

MICROPLANKTON CHARACTERIZATION

10 December 1970

Station	1		2		4		5		12
Time	1315	1320	1400	1410	1325	1330	1250	1255	1130
Depth (ft)	1	37	1	17	1	48	1	36	1
Total Conc. (10^3 org./l)	14.4	13.3	5.0	17.0	12.0	20.0	15.8	30.5	10.8
CHLOROPHYCOPHYTA									
Chlorophyta		2.0	1.0	1.0		1.0	4.4	1.7	1.2
CHRYSOPHYCOPHYTA									
Centrales									
Asteromphalus sp.	1.2								
Biddulphia sp.						1.0			
Chaetoceros sp.						2.0		0.9	
Coscinodiscus sp.	3.6	8.3	3.0	6.0	1.0	7.0		6.1	
Melosira sp.						4.0			
Planctoniella sp.	1.2		1.0						
Rhizosolenia sp.		1.0				2.0	0.9		1.2
Skeletonema sp.				5.0	4.0			13.9	7.2
Thalassiosira sp.				4.0	4.0	2.0	5.2	6.1	
Other Centrales		1.0							
Pennales									
Navicula sp.	1.2					1.0	0.9		1.2
Nitzschia sp.		1.0					1.7	0.9	
Other Pennales				1.0			0.9	0.9	
Other CHRYSOPHYCOPHYTA	1.2				1.0				

TABLE IV-17 (Cont'd)

Station	1		2		4		5		12
Time	1315	1320	1400	1410	1325	1330	1250	1255	1130
Depth (ft)	1	37	1	17	1	48	1	36	1
Total Conc. (10^3 org./l)	14.4	13.3	5.0	17.0	12.0	20.0	15.8	30.5	10.8
PROTOZOA									
MASTIGOPHORA									
Dinoflagellata									
Gonyaulax sp.					1.0				
Other MASTIGOPHORA				1.0			0.9		
CILIATA									
Spirotrichia									
Tintinnidae							0.9		

of three and a maximum of eight varieties appearing in an individual sample.

SEDIMENT QUALITY

Samples from the receiving water (nearshore) stations were examined for particle-size distribution, hexane extractable materials, total nitrogen, and sulfide content, as well as for the composition of benthic animals. Beach sediments were examined for hexane extractable materials.

Nearshore Sediments

The results of the physicochemical analyses conducted on sediments from nearshore stations on 10 December 1970 are presented in Table IV-18.

Particle size analyses indicated that samples were composed predominantly of sandy particles having a diameter of at least 0.208 mm. The present composition of sand ranged from 60.4 at Station 2 to 90.7 at Station 5.

The mean concentration of hexane extractable materials was 0.448 mg/g of dry sediment, with respective low and high values at Stations 5 and 2. The mean value approximates the hexane extractable materials level of 0.400 mg/g reported for the Central Bay area (Reference 1).

Total nitrogen values ranged from 0.372 to 0.790 mg/g of dry sediment. These values are below the norm of 3 to 4 mg/g reported for the Central Bay (Reference 1).

Total sulfide values ranged from a low of 24.7 mg/kg of dry sediment at Station 1 to a high of 358 mg/kg at Station 2. These data support the concept (presented in Reference 1) that high sulfide concentrations are associated with a relatively low percentage of sand composition.

Results of the benthic animal classification and enumeration performed on the nearshore sediments collected on 10 December 1970 are listed in Table IV-19. Species diversity values ranged from 1.80 at Station 1 to 3.59 at Station 2. A minimum of 11 and a maximum of 22 varieties of animals were represented in any single sample. With the exception of Station 5, which was dominated by a single species of Nematode worms, organisms of the annelid-type represented the largest single classification of organisms.

TABLE IV-18

PHYSICOCHEMICAL CHARACTERISTICS OF NEARSHORE SEDIMENTS

10 December 1970

Station	Particle-Size Distribution (%)			HEM (mg/g)	Total Nitrogen (mg/g)	Total Sulfide (mg/kg)
	>.208 mm	.208 to .053 mm	<.053 mm			
1	69.1	9.8	21.1	0.435	0.790	24.7
2	60.4	16.6	23.0	0.915	0.435	358.0
4	76.2	6.7	17.1	0.255	0.434	94.1
5	90.7	3.0	6.3	0.185	0.372	32.0

TABLE IV-19

BENTHIC ANIMAL DATA

10 December 1970

Identification	Station 1	Station 2	Station 4	Station 5
ANNELIDA				
OLIGOCHAETA	29	23	21	
POLYCHAETA				
Cirratulidae		1		
Glyceridae				
Glycera capitata	3			
Glycera convoluta				1
Glycera tesselata				1
Glycera sp.		1		
Hemipodus sp.				1
Goniadidae				
Glycinde armigera				1
Goniada sp.		1		
Nephtyidae				
Aglaophamus dicirrus				1
Nephtys sp.	18	33	14	
Opheliidae				
Armandia bioculata	1			1
Travisia sp.		1		
Orbiniidae				
Haploscoloplos sp.	2	1		
Orbinia sp.		3		
Scoloplos acmeceps	1			
Oweniidae				
Owenia sp.	1			2
Pectinariidae				
Pectinaria californiensis		2	2	
Phyllodocidae				
Anaitides mediapapillate		2		
Syllidae			1	
Unidentified	1	3	2	
ARTHROPODA				
AMPHIPODA		34		1
CIRRIPEDIA				
Balunus glandula	1			
CUMACEA	1	13	3	

TABLE IV-19 (Cont'd)

Identification	Station			
	1	2	4	5
BRYOZOA				
Crisia geniculata	f			
Unidentified	f	f		
COELENTERATA				
ANTHOZOA				
Acanthoptilum sp.		4		
HYDROZOA				
Abietinaria filicula	f[1]			f
Aglaophenia inconspicua	f	f	f	f
Aglaophenia struthionides	f			
Companularia sp.	f			
Sertularia pulchella	f			
Unidentified	f			
MOLLUSCA				
PELECYPODA				
Macoma inconspicua	4	8		
Macoma nasuta	4	1	3	
Macoma secta			2	
Macoma sp.				2
Tellina bodegensis	1			3
Transennella tantilla	3			3
Volsella demissus		3		2
Volsella sp.	1			
Unidentified				1
NEMATODA	41			72
NEMERTEA		5	2	1
SIPUNCULOIDEA				
Sipunculus sp.	3	6		1
Unidentified	2			
UNIDENTIFIED	6			
Volume of Organisms (ml/l sed.)	1.1	0.8	0.8	1.3
Total No. of Organisms	131	147	51	96
Number of Entries[2]	20	22	11	16
Diversity Value	3.40	3.59	3.01	1.80

[1] f = fragments

[2] Fragments not included

Intertidal Sediments

The contents of hexane extractable materials in the sediments collected from the intertidal zone on 26 December 1970 were quantified and the results are presented in Table IV-20. Values ranged from 0.072 to 0.174 mg/g, with a mean of 0.133 mg/g. The area considerably west of Baker Street, represented by Stations 5B and 6B demonstrated slightly lower values of hexane extractable materials than the area immediately onshore of the Baker Street outfall.

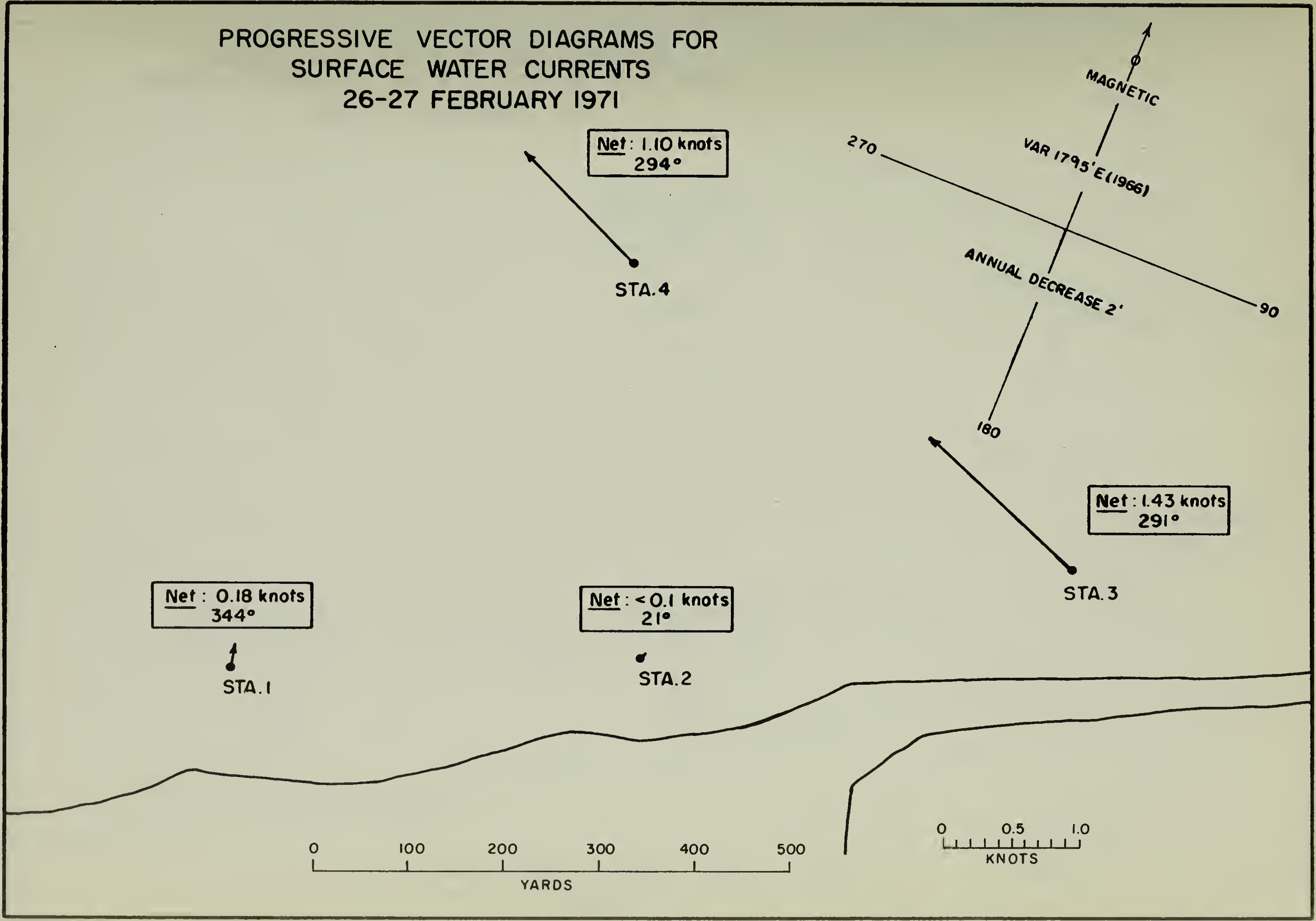
TABLE IV-20

PHYSICOCHEMICAL CHARACTERISTICS OF BEACH SEDIMENTS

23 December 1970

Station	Sample Appearance	HEM (mg/g)
1B	Sand	0.174
2B	Sand	0.144
3B	Sand	0.172
4B	Sand	0.135
5B	Sand	0.103
6B	Sand	0.072

FIGURE IV-1



PROGRESSIVE VECTOR DIAGRAMS FOR SURFACE WATER CURRENTS 26-27 FEBRUARY 1971

FIGURE IV-2

PROGRESSIVE VECTOR DIAGRAMS FOR WATER CURRENTS AT A DEPTH OF FIVE FEET 26-27 FEBRUARY 1971

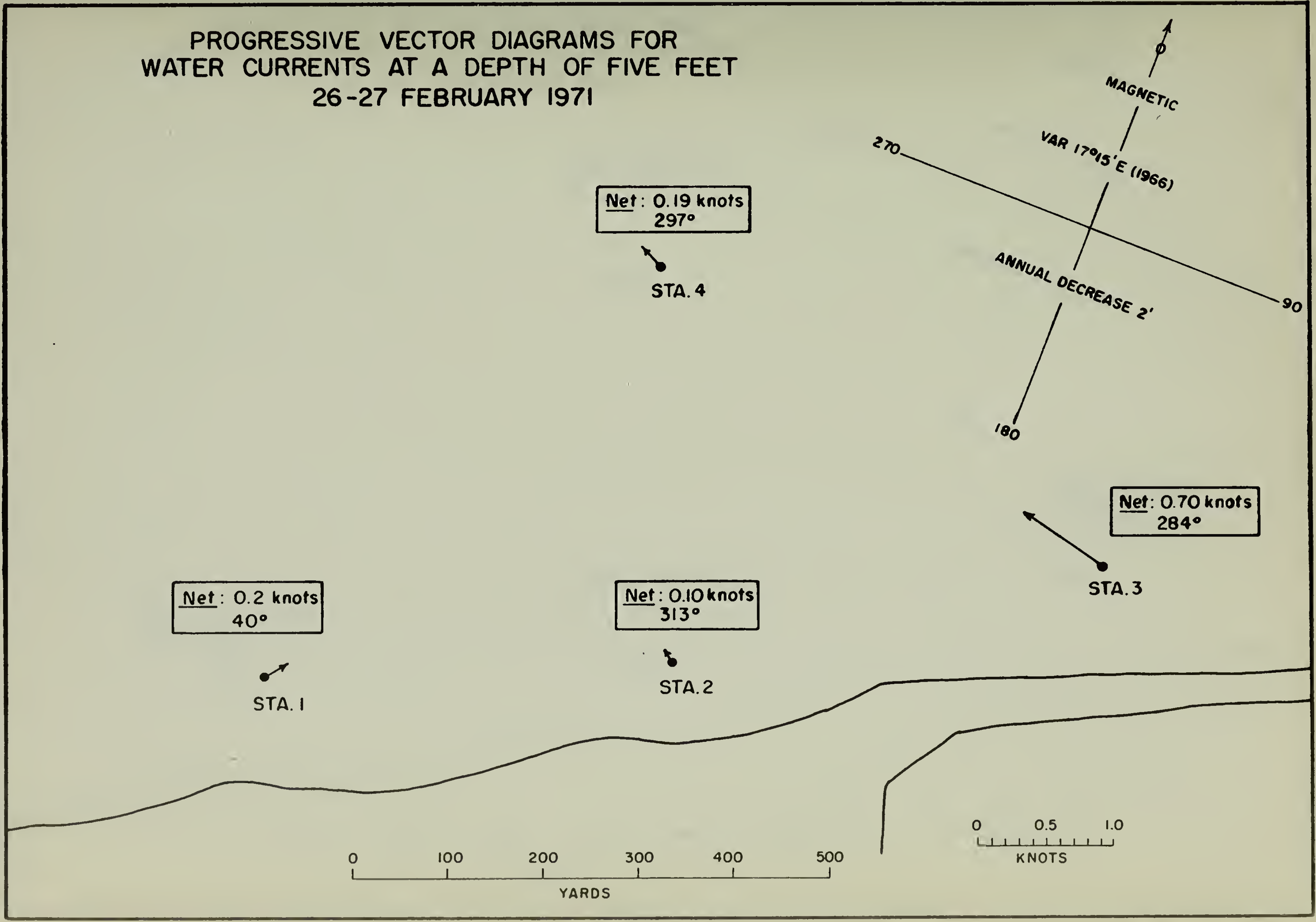
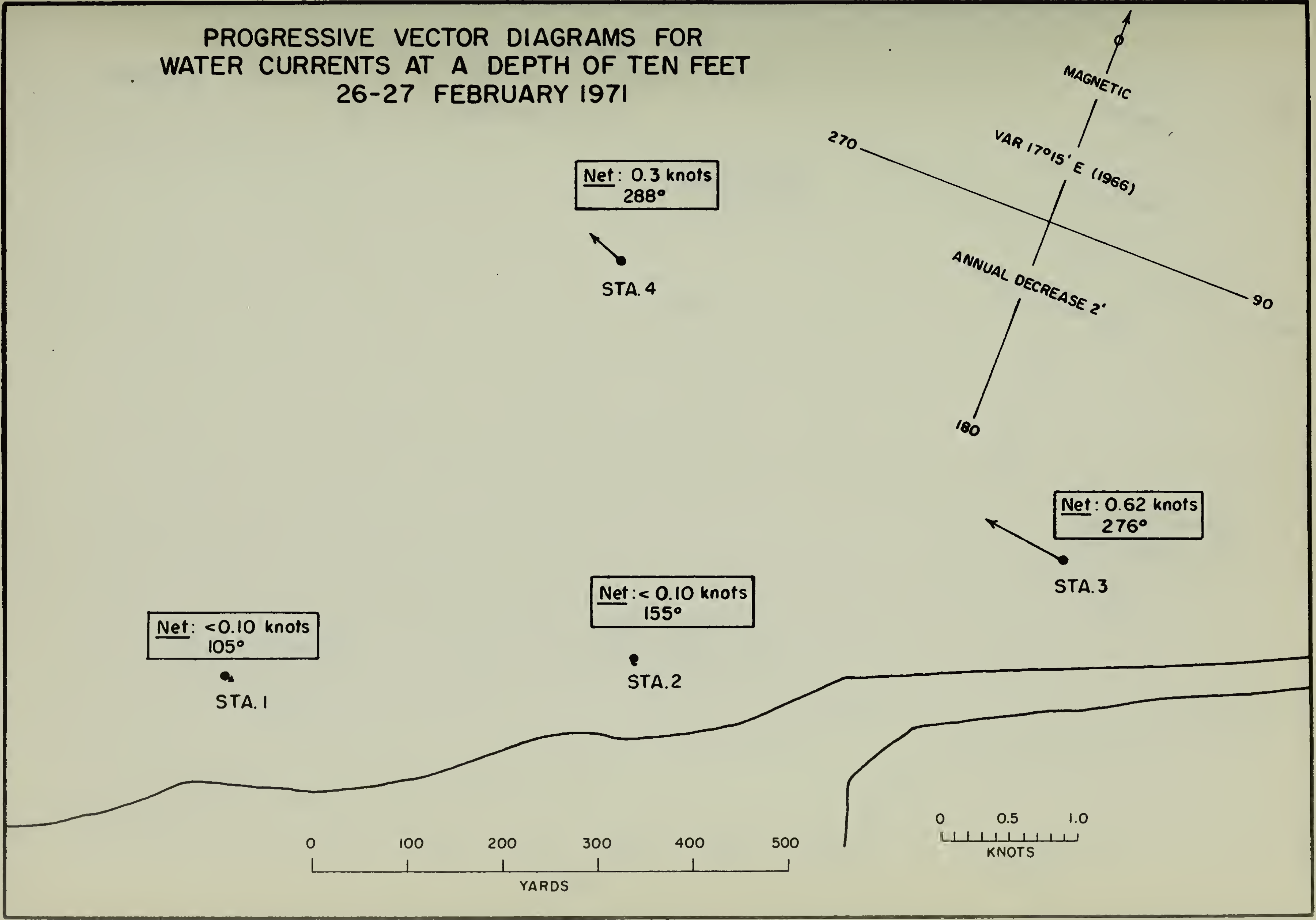


FIGURE IV-3

PROGRESSIVE VECTOR DIAGRAMS FOR WATER CURRENTS AT A DEPTH OF TEN FEET 26-27 FEBRUARY 1971



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PROGRESSIVE VECTOR DIAGRAMS FOR WATER CURRENTS AT A DEPTH OF TWENTY FEET 26-27 FEBRUARY 1971

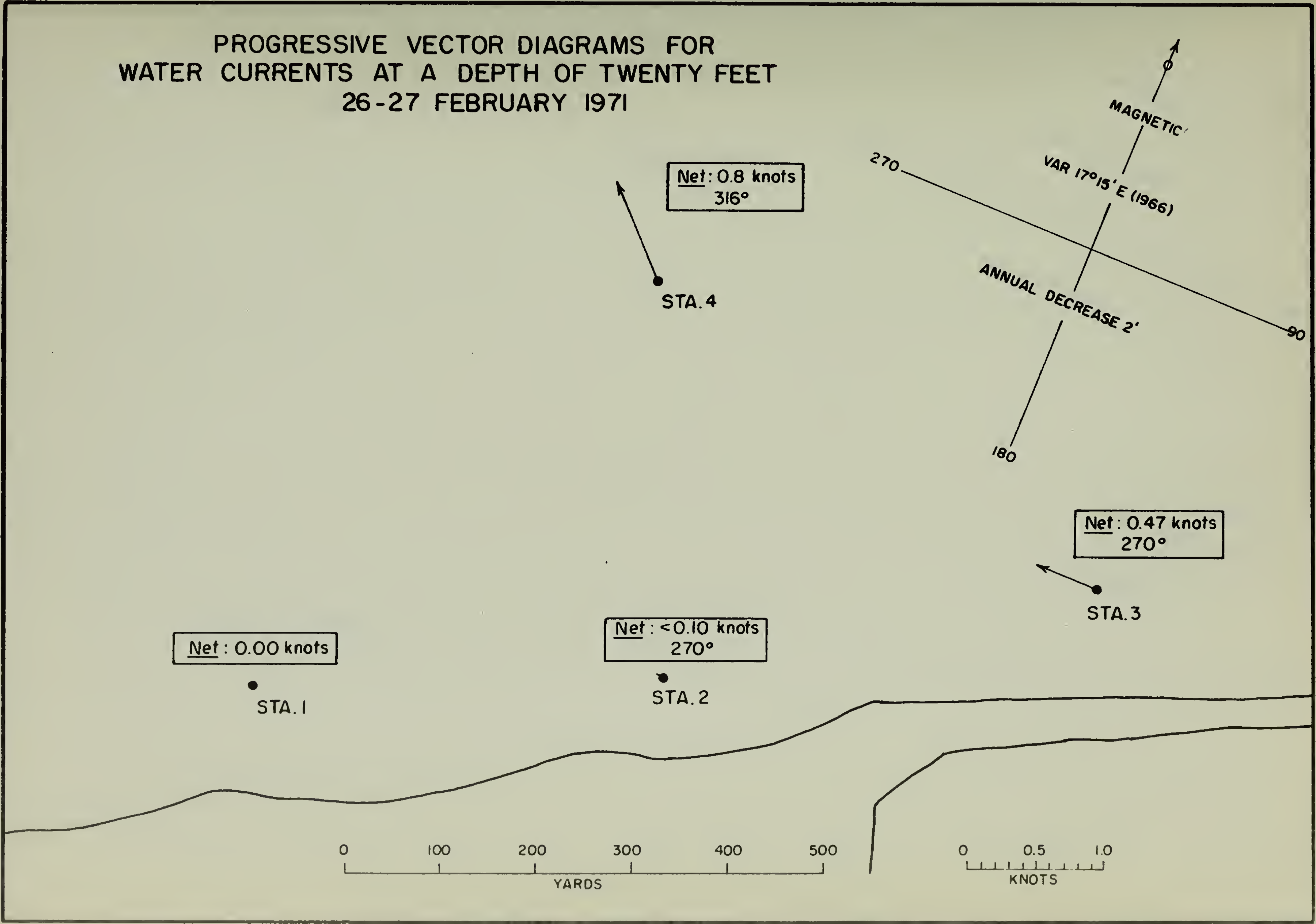
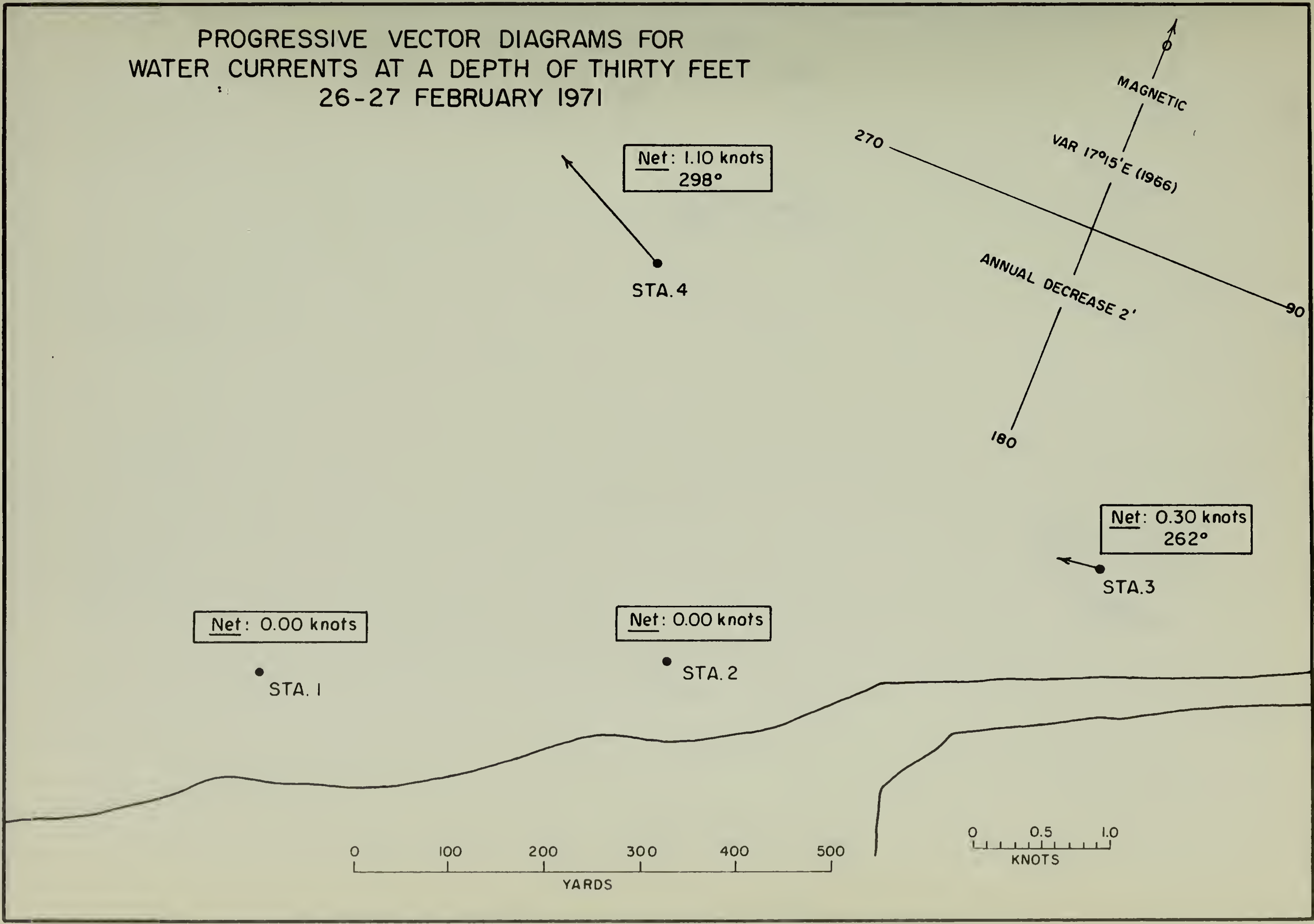


FIGURE IV-5



PROGRESSIVE VECTOR DIAGRAMS FOR
WATER CURRENTS AT A DEPTH OF THIRTY FEET
26-27 FEBRUARY 1971

FIGURE IV-6

PROGRESSIVE VECTOR DIAGRAMS FOR WATER CURRENTS AT A DEPTH OF FORTY FEET 26-27 FEBRUARY 1971

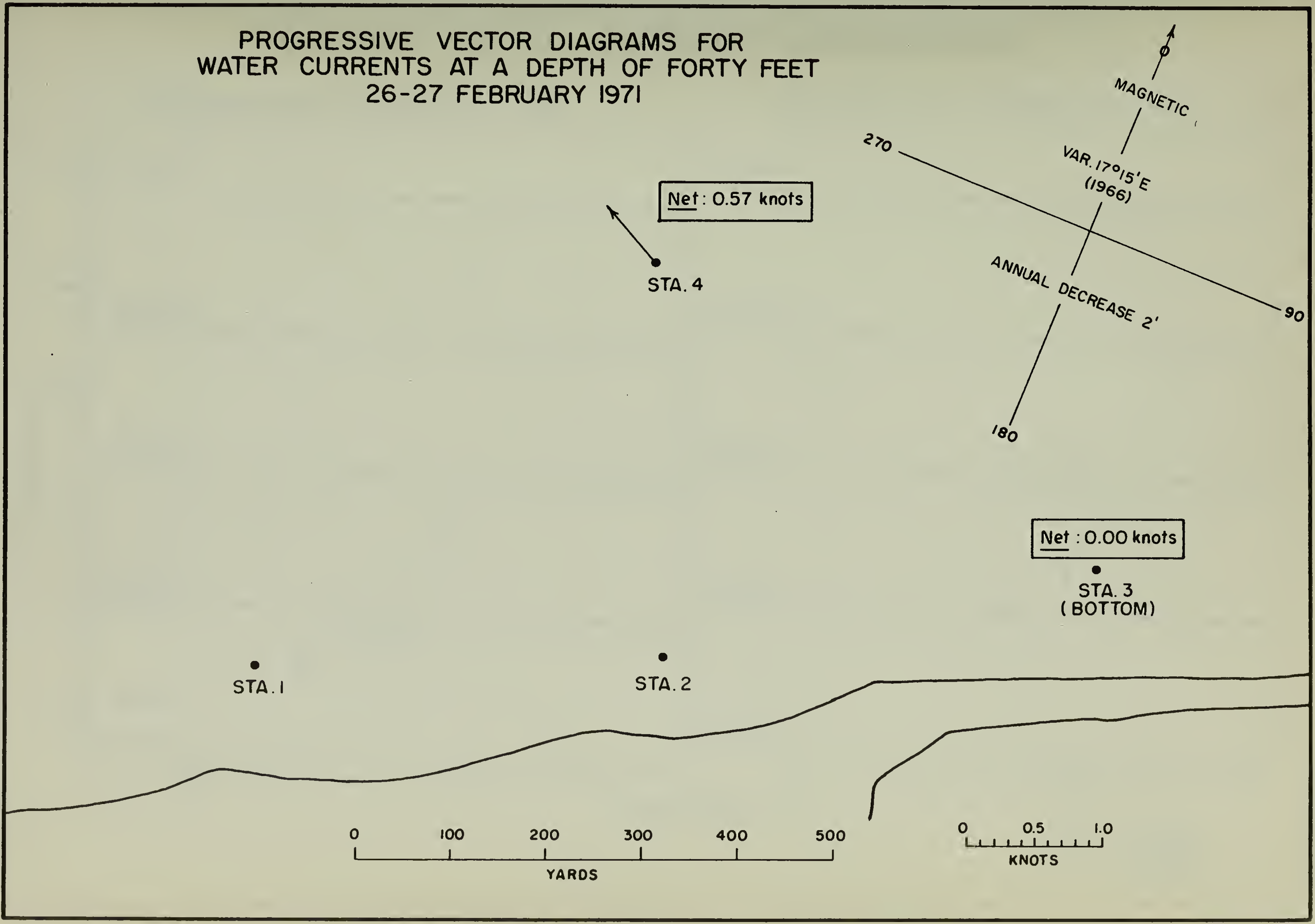


FIGURE IV-7

TEMPERATURE, SALINITY, AND DENSITY CHARACTERISTICS

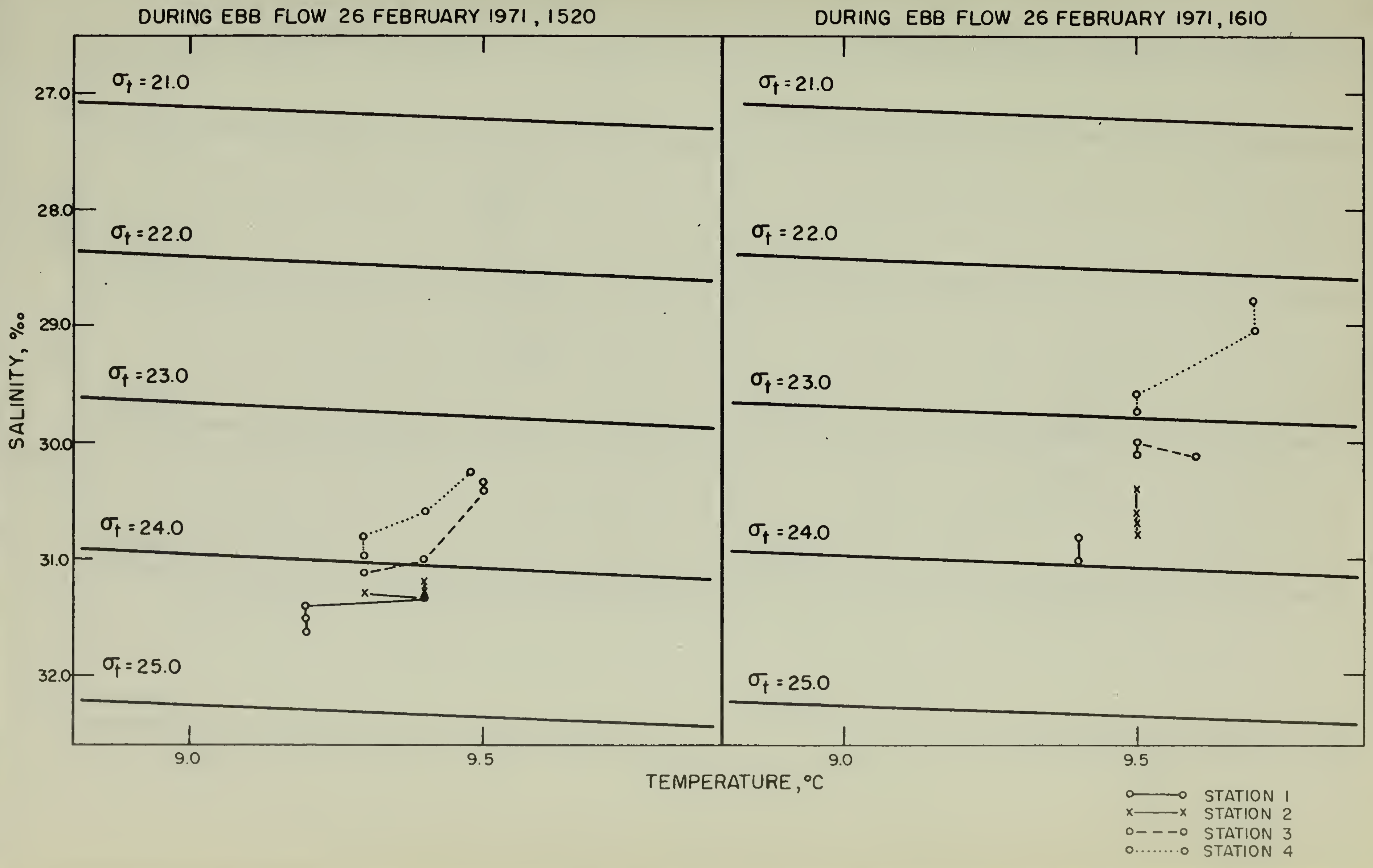
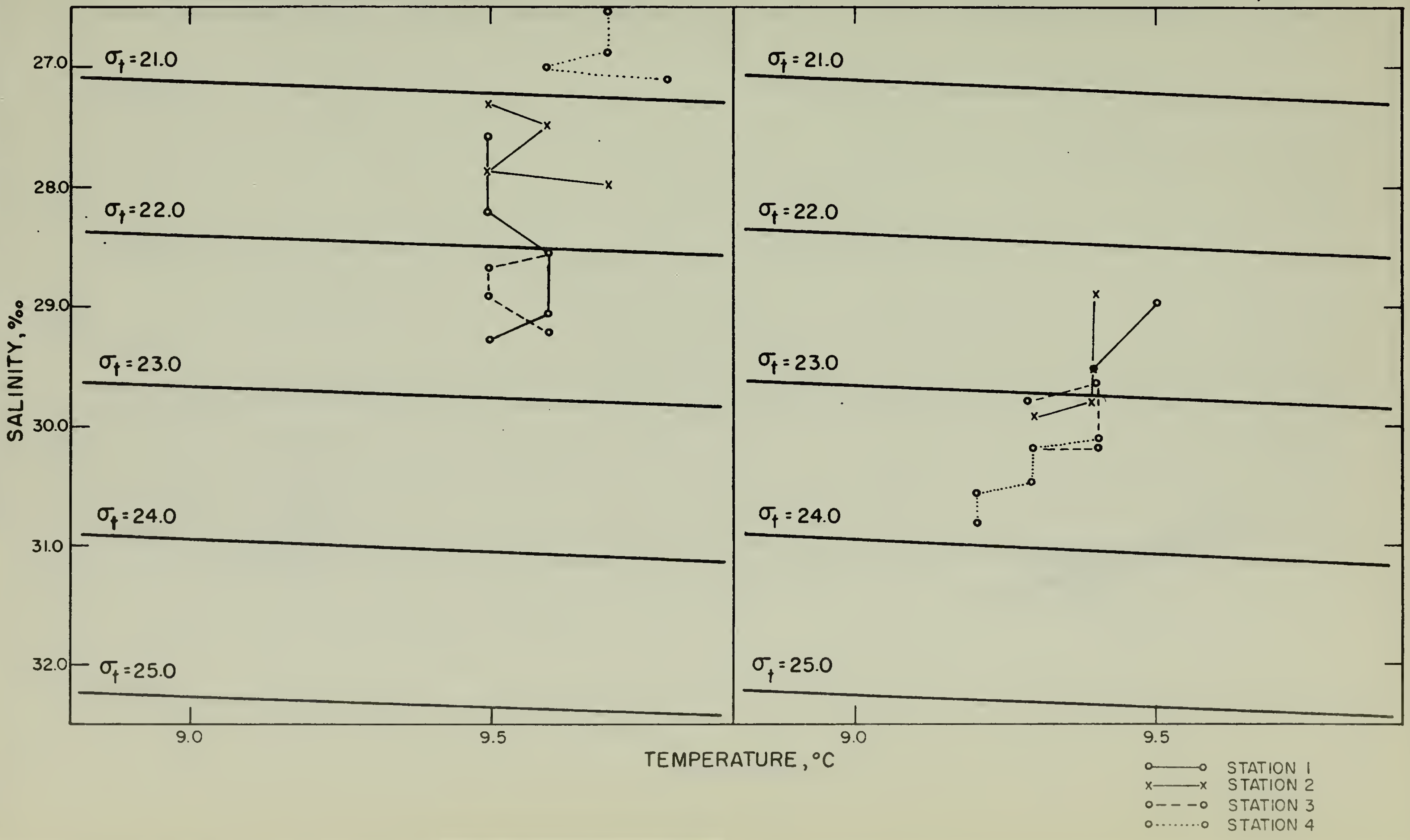


FIGURE IV-8

TEMPERATURE, SALINITY, AND DENSITY CHARACTERISTICS

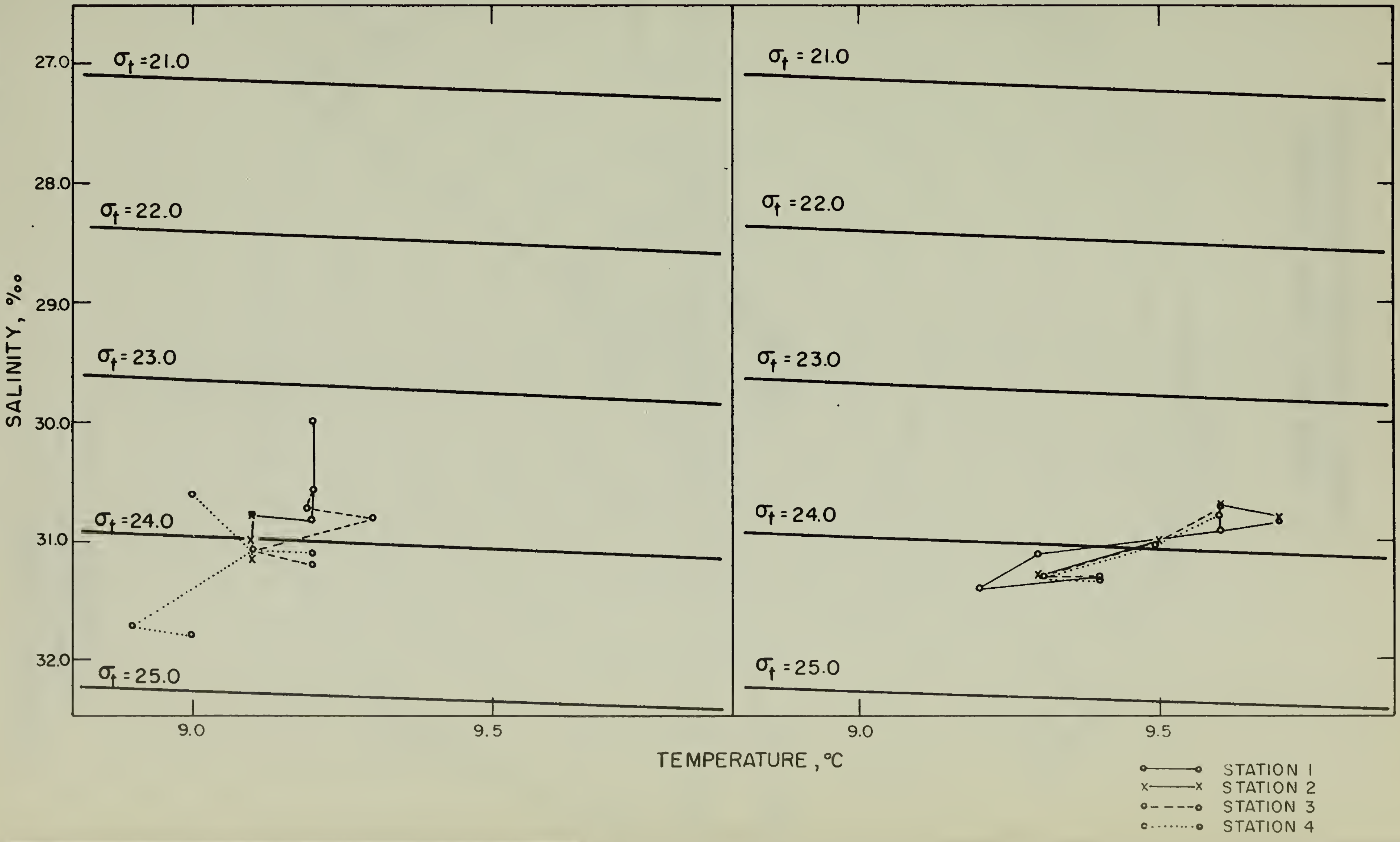


DURING DEVELOPMENT OF LOW SLACK
26 FEBRUARY 1971, 2100

AT LOW SLACK 26 FEBRUARY 1971, 2240

FIGURE IV-9

TEMPERATURE, SALINITY, AND DENSITY CHARACTERISTICS



DURING FLOOD TIDE 27 FEBRUARY 1971, 0025

DURING THE DEVELOPMENT OF HIGH SLACK
26 FEBRUARY 1971, 1320

FIGURE IV-10

WIND CONDITIONS FOR SPRING
(MARCH, APRIL, AND MAY)

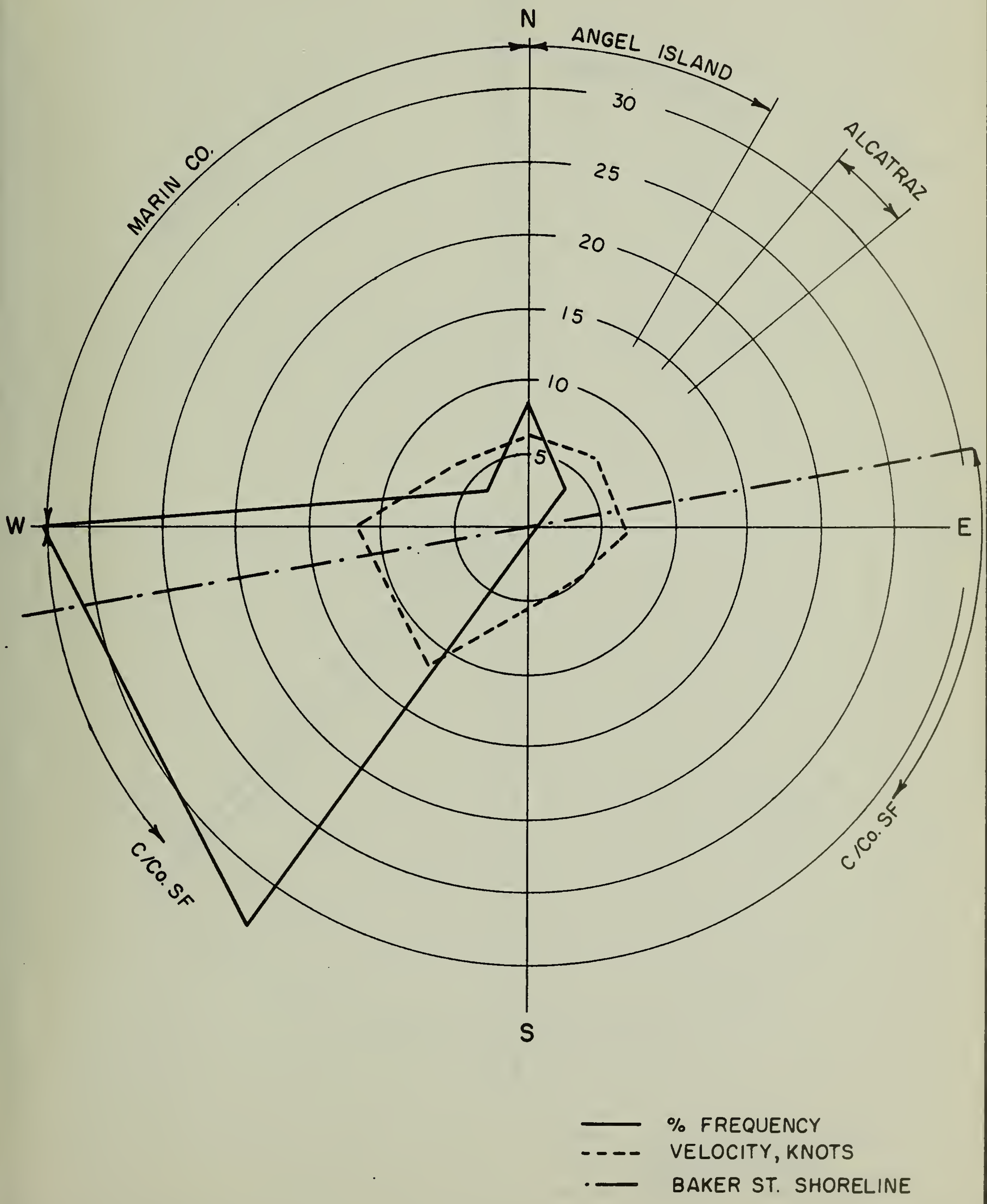


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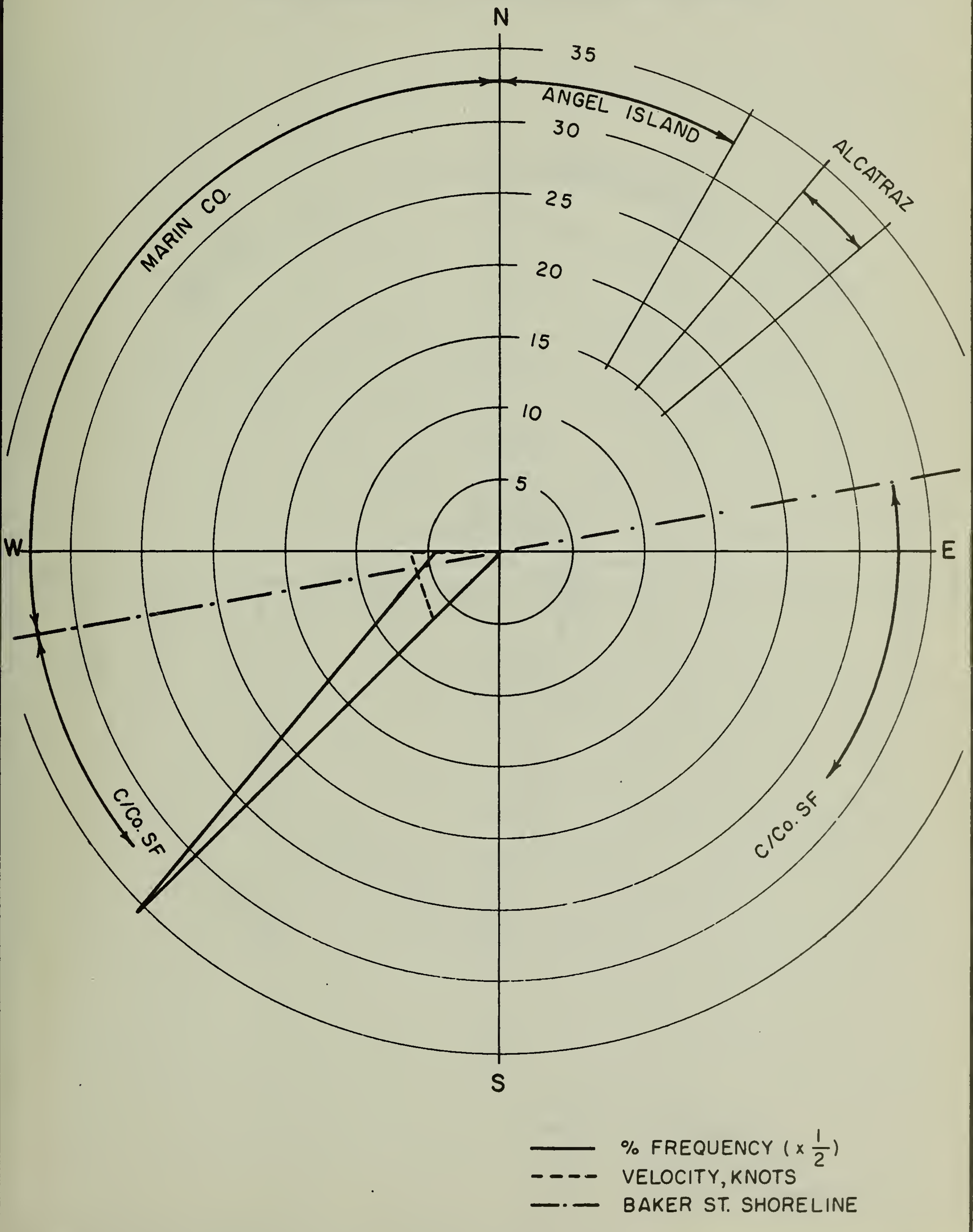
FIGURE IV-11

WIND CONDITIONS FOR SUMMER (JUNE, JULY, AND AUGUST)



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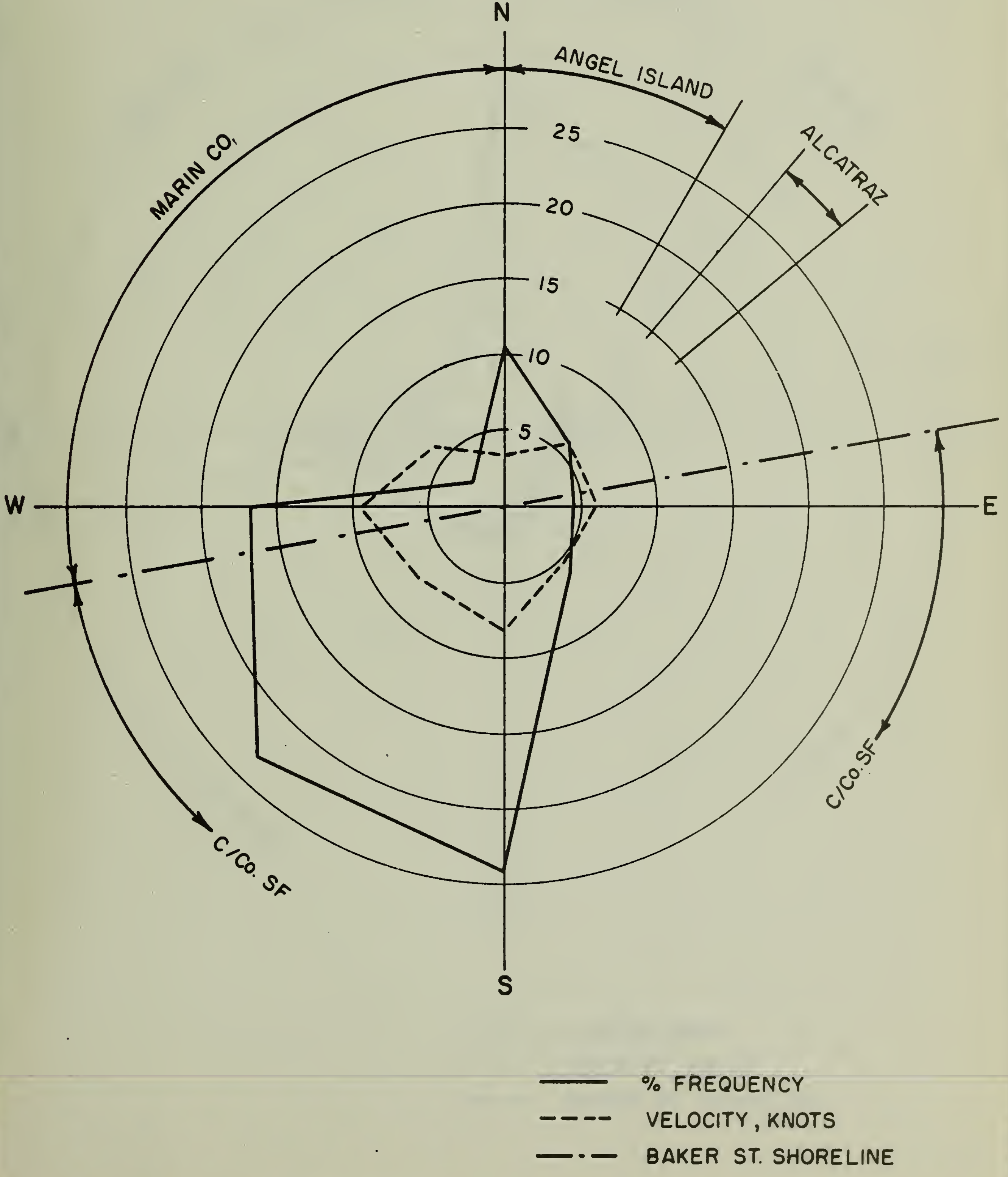
WIND CONDITIONS FOR FALL
(SEPTEMBER, OCTOBER, AND NOVEMBER)



WIND CONDITIONS FOR WINTER (DECEMBER, JANUARY, AND FEBRUARY)

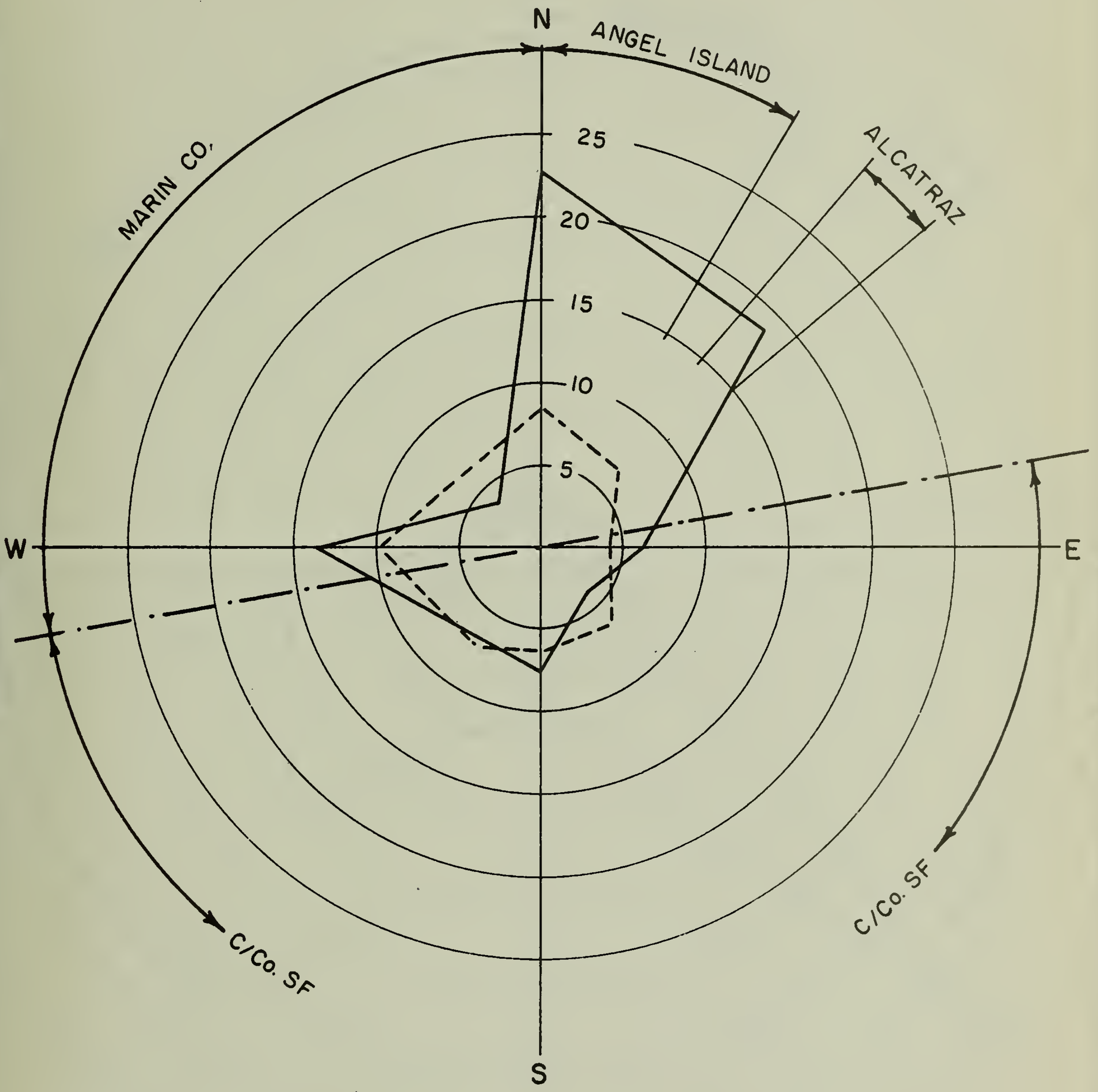


FIGURE IV-14

WIND CONDITIONS DURING RAINY PERIODS (RAINFALL ≥ 0.02 INCHES)

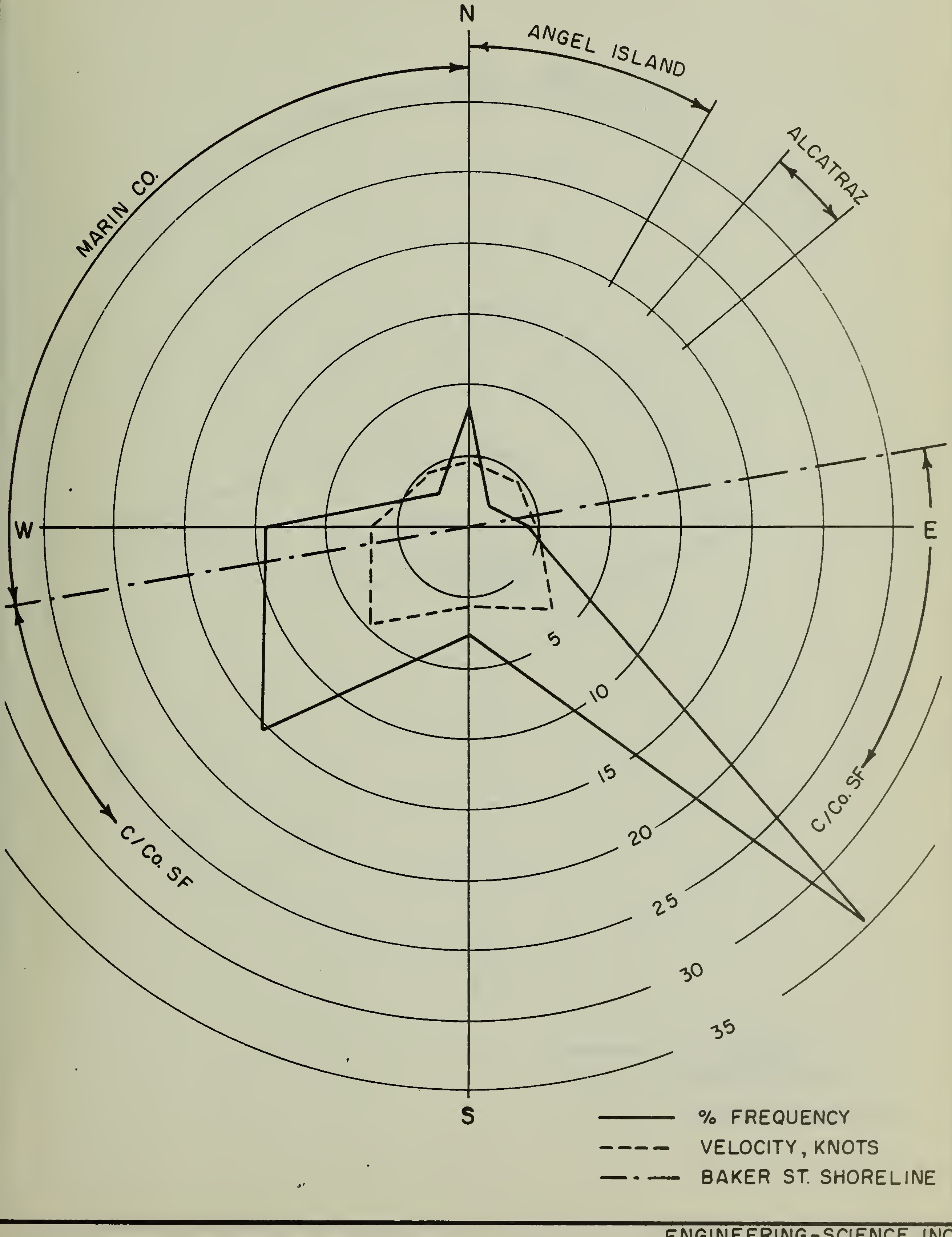


FIGURE IV-15

WIND CONDITIONS ONE DAY AFTER OCCURRENCE OF RAINY DAY

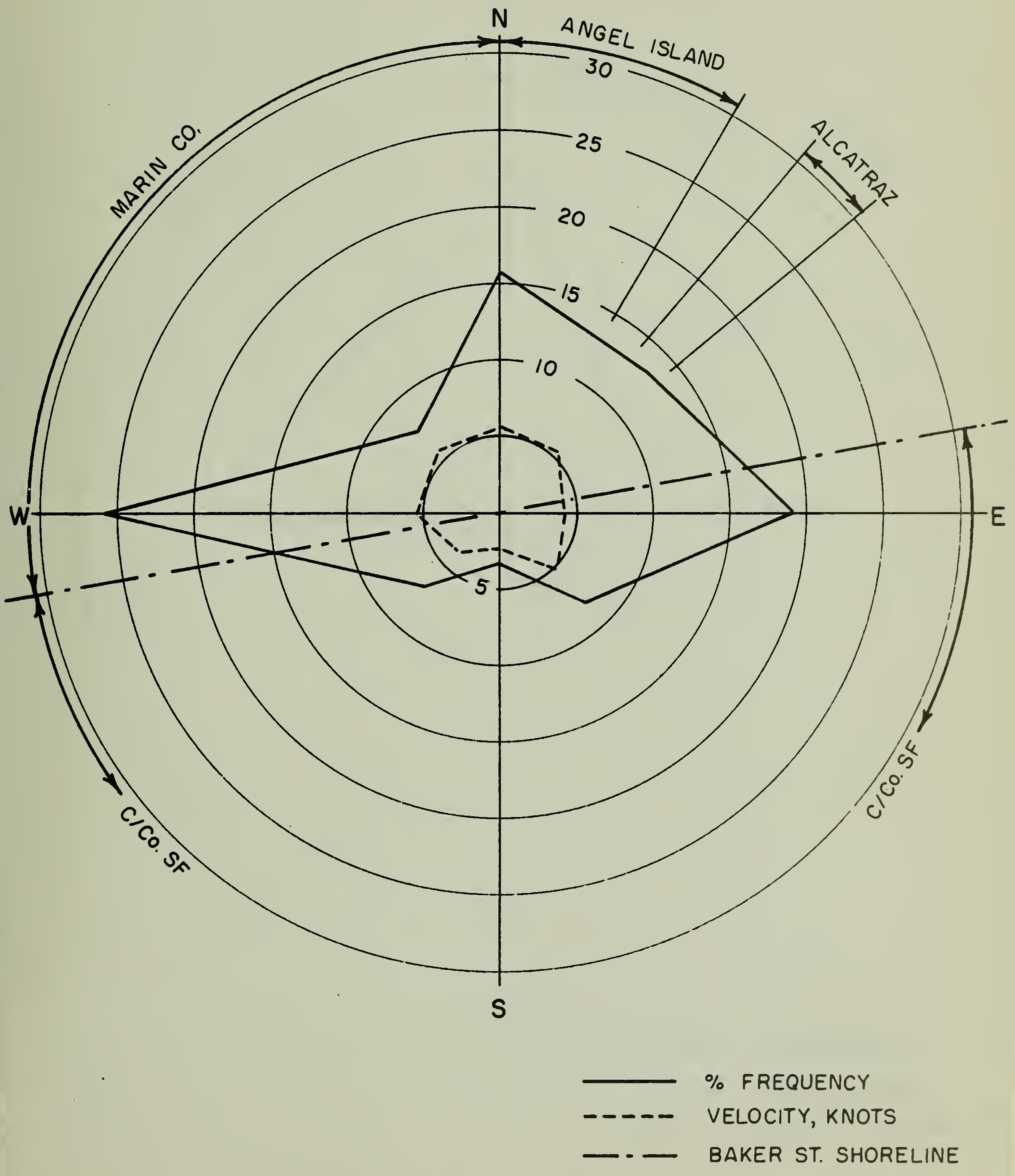


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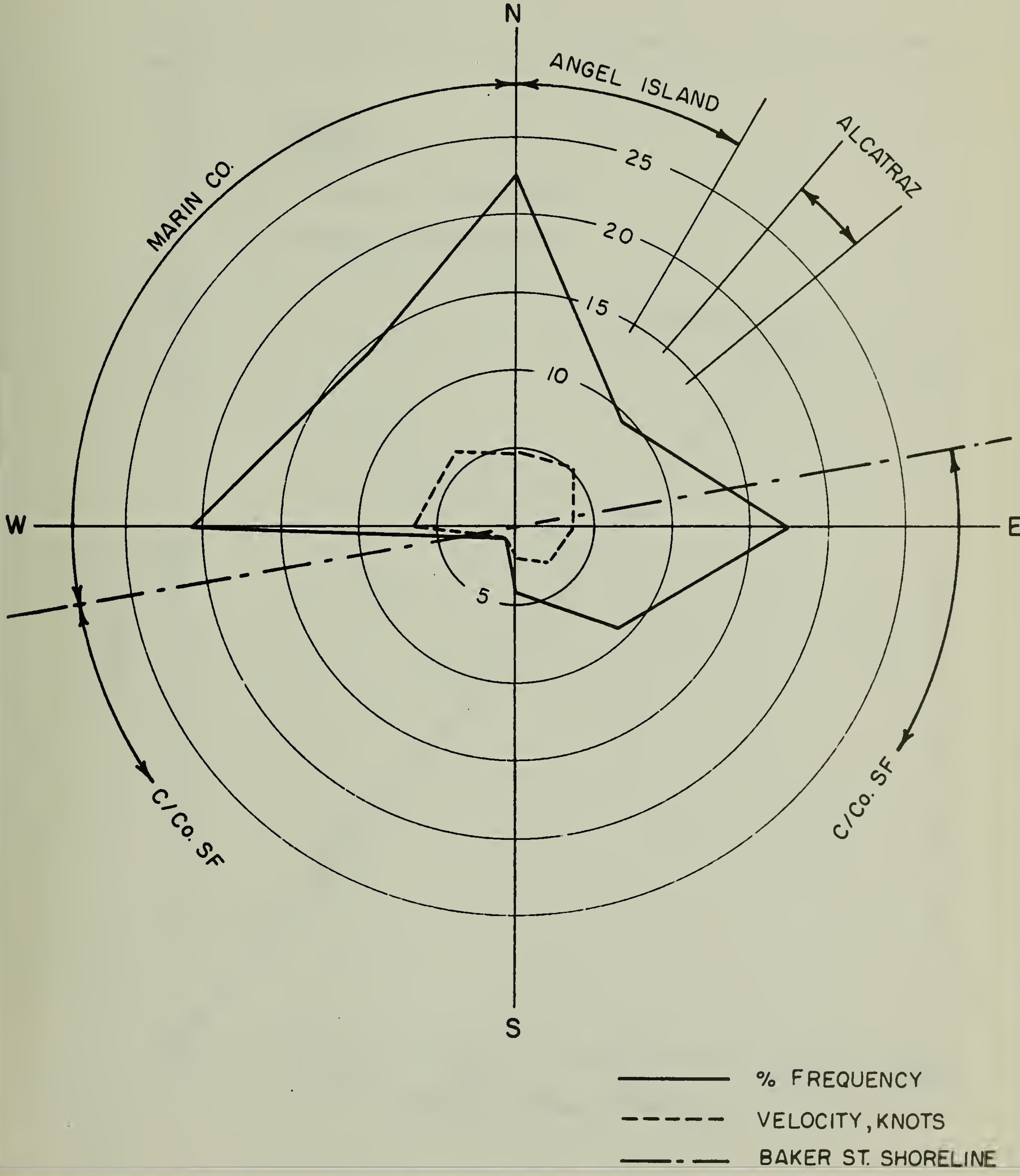
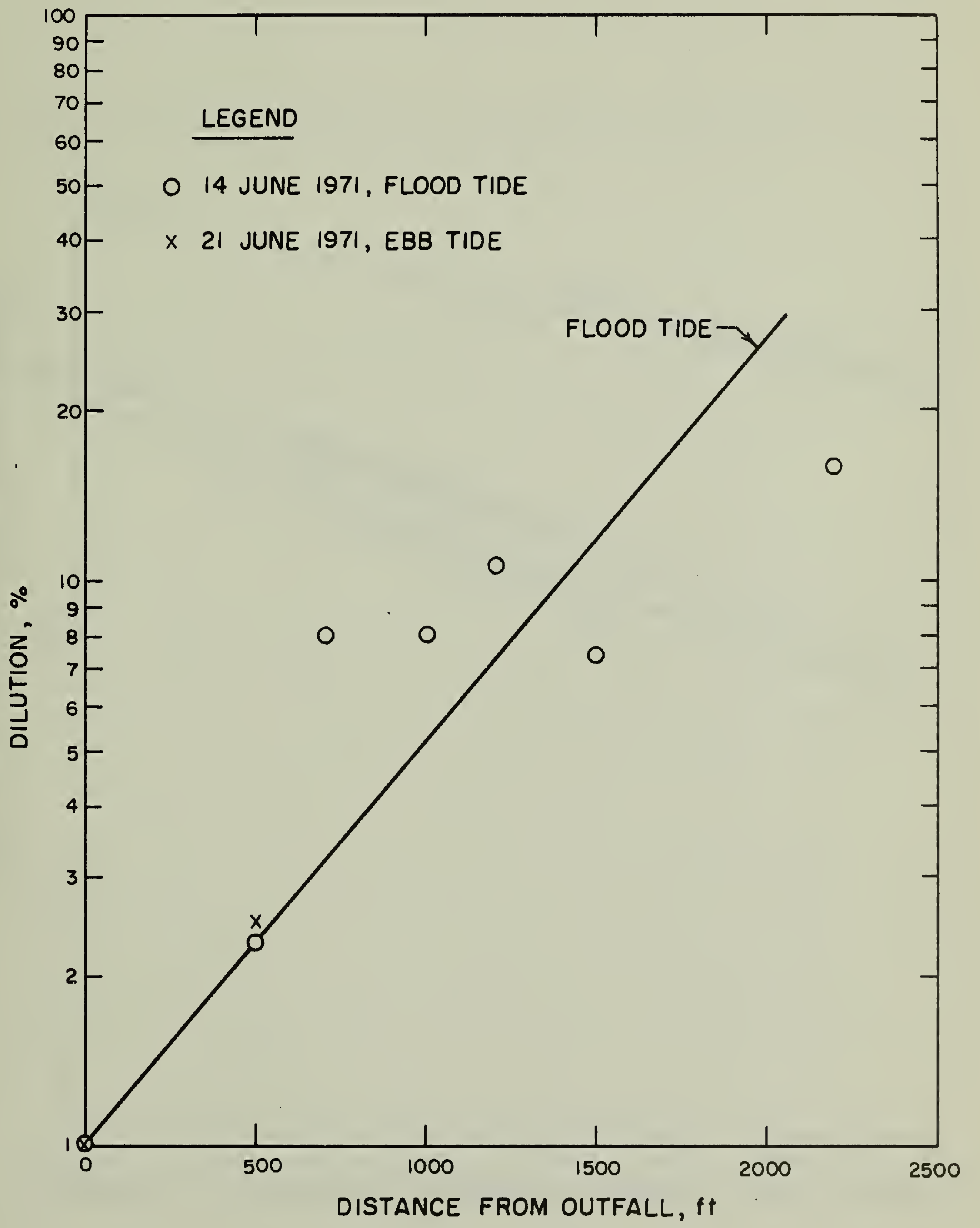
FIGURE IV-16

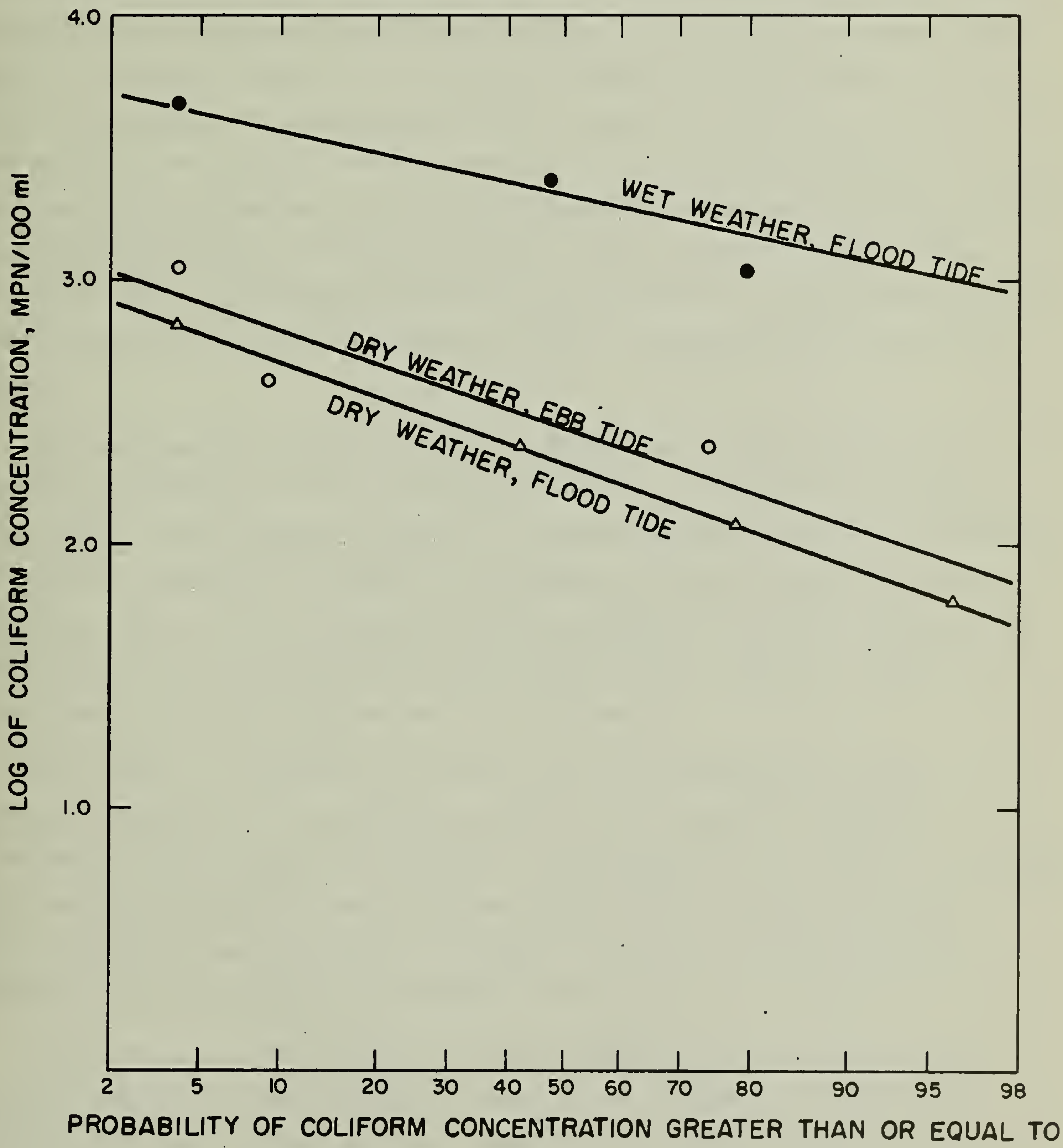
WIND CONDITIONS TWO DAYS AFTER OCCURRENCE OF RAINY DAY



HORIZONTAL SURFACE DISPERSION OF RHODAMINE WT DYE IN BAKER STREET RECEIVING WATERS



PROBABILITY OF OCCURRENCE OF COLIFORM CONCENTRATIONS IN BAKER STREET RECEIVING WATERS WITHOUT THE OPERATION OF DISSOLVED AIR FLOTATION FACILITY



CHAPTER V

CONCLUSIONS

The wet-weather and dry-weather receiving water standards established by the California Regional Water Quality Control Board serve as a base for the evaluation of water quality in the study area. Specified in the requirements are quantitative limits for pH, dissolved oxygen, and dissolved sulfide levels, and bacterial concentrations. The receiving waters adjacent to the Baker Street outfall currently meet the requirements for pH, dissolved oxygen, and dissolved sulfides. However, the high levels of coliform bacteria during wet weather have been and presently continue to be the prime area of concern for the maintenance of acceptable receiving water quality established by the Regional Water Quality Control Board. The results of this study demonstrate the high probability (96 percent) of the waters exceeding the required bacteriological concentrations during wet weather.

The Regional Water Quality Control Board has listed also a series of subjective standards as being necessary for the protection of the beneficial uses of the receiving waters. These standards include a consideration of the character and levels of floatable and particulate materials, turbidity, color, oil and grease in bottom deposits, aquatic growths, and the availability of substances which promote and/or inhibit productivity in the receiving water and sediment environments.

The results of the study indicate that the character and level of floatable materials in the receiving waters are primarily dependent on wet-weather or dry-weather conditions, and secondarily on tides and currents. High levels of floatable materials are likely to be found during wet-weather and ebb tide conditions, whereas relatively low levels can be expected to occur during dry weather at flood tide.

An analysis of the results of a continuous monitoring survey for turbidity levels in the receiving waters did not reveal any consistent patterns or trends. The turbidity levels in the receiving waters can, for present experimental purposes, be considered to be fairly uniform at a level of 30 to 32 percent.

In view of the fact that the concentrations of hexane extractable materials (predominantly oil and grease) in the receiving water sediments in the vicinity of the Baker Street outfall approximates the mean concentration reported for the Central Bay, it appears that there are currently no objectionable deposits which can be specifically attributed to the Baker Street outfall.

The productivity of receiving waters is represented by the microplankton, whereas the level of sediment productivity is reflected in the benthos of the nearshore sediments. Both the concentrations of microplankton in the receiving waters and benthic animals in the sediments were low and represented by a number of varieties. The combination of low and diverse populations is considered, generally, to be representative of a balanced ecology.

CHAPTER VI

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APPENDIX G

DISSOLVED AIR FLOTATION

PERFORMANCE EVALUATION OF BAKER STREET FACILITY WITH RAW SEWAGE

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DISSOLVED AIR FLOTATION

APPENDIX G

PERFORMANCE EVALUATION OF BAKER STREET FACILITY WITH RAW SEWAGE

Part of City and County of San Francisco's
Master Plan Study for Wet Weather Control Program

submitted by

City and County of San Francisco, California

prepared by

Engineering-Science, Inc.
Research and Development Laboratory/Berkeley

for

Environmental Protection Agency
Water Quality Office

July 1971

FOREWORD

This volume constitutes the seventh of seven technical appendices to the Project Report on Treatment of Combined Sewer Overflows by the Dissolved Air Flotation Process. Appendices in this series are:

A. Phase I - Pre-Construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach

B. Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility

C. Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process - A Pilot Plant Study

D. Design Factors for Baker Street Dissolved Air Flotation Facility

E. Costs for Dissolved Air Flotation Facilities

F. Characterization of the Receiving Water and Beach Intertidal Zone Environment

G. Performance Evaluation of Baker Street Facility with Raw Sewage

Appendix G is submitted in partial fulfillment of DPW Order No. 80,480 between the City and County of San Francisco and Engineering-Science, Inc., and was supported in part by Grant WPRD-258-01-68 between the Environmental Protection Agency, Water Quality Office, and the City and County of San Francisco, Department of Public Works.

This report, prepared in limited edition for utilization in City and County of San Francisco's Master Plan study for wet-weather control, is under review for approval by the Environmental Protection Agency, Water Quality Office.

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CHAPTER I

INTRODUCTION

In October 1970 the City and County of San Francisco completed the construction of the 24-mgd dissolved air flotation plant at the Outer Marina Beach for treatment of combined sewer overflows. A program to demonstrate the operation and performance of this (the prototype) facility during the wet-weather flow conditions between October 1970 and March 1971 was postponed due to initial startup problems at the facility and unforeseen hydraulic conditions in the sewerage system and bypass structure tributary to the plant. To provide information on the performance of the dissolved air flotation process for the treatment of combined sewer overflows within the time constraints of the present contract, a pilot-scale study (Appendix C, *Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process--A Pilot Plant Study*) and a protoytpe program were conducted with dry-weather flow, or raw and diluted raw sewage.

Use of dry-weather flow (raw and diluted raw sewage) to evaluate performance of a process for the treatment of wet-weather flow (combined sewer overflows) was justified on the basis that the concentrations of affected pollutants in combined sewages, and for that matter separated storm water runoff, are not substantially different from those in raw sanitary sewage.

This report describes the program and presents results of the prototype study conducted at the Baker Street dissolved air flotation facility with diverted dry-weather flow.

CONDUCT

The prototype studies were initiated with the completion of construction and installation of a shear gate system at a manhole on Marina Boulevard in San Francisco. The studies were conducted at the Baker Street dissolved air flotation facility from late May through late June 1971, and encompassed the mapping of the process performance curves (or response

surfaces) of the dissolved air flotation process for treatment of raw sewage.

ORGANIZATION

The prototype study was performed by the staff of the Research and Development Laboratory/Berkeley, Engineering-Science, Inc., under the direction of Dr. D.L. Feuerstein. Project staff included Messrs. Osita Udoh, William Maddaus, Jeet Sehgal, and Gary Zimmerman.

The assistance of members of the staff of the Department of Public Works, City and County of San Francisco, is gratefully acknowledged.

ACKNOWLEDGMENTS

This investigation was funded in part by the Facility Demonstration Grant Project No. WPRD-258-01-68 of the Environmental Protection Agency, Water Quality Office.

CHAPTER II

STUDY CONCEPT

THE DISSOLVED AIR FLOTATION PROCESS

A simplified flow sheet for the dissolved air flotation process is shown in Figure II-1. Raw waste was mixed with pressurized recycle flow in the inlet section of the flotation chamber. Chemicals were added to either the influent or the pressurized recycle flow to effect destabilization of colloidal particles and to aid in the formation of air-solids aggregates. Air pressurization was done by the injection of air into the suction side of a centrifugal pump. Turbulence in the piping system and the mechanical shear of the centrifugal pump served to implement the mixing and contact of air, chemicals, and solids in the process.

The inputs to the process are air, chemicals, and influent wastewater, and the outputs from the process are sludge (a dilute stream), float (a concentrated stream), and treated effluent.

Process Variables

The process parameters selected to describe the process-level inputs and outputs of dissolved air flotation have been described in Appendix B, ***Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility.*** Because the application of dissolved air flotation in the present study relates to dilute streams of less than 1,000 mg/l suspended solids, influent liquid loading rate was selected as the first appropriate variable. The quantification of the size, number, and character of air bubble-particle aggregates formed in this application cannot be accomplished at the present time, so that several implicit parameters were selected as measures of the potential for air bubble-particle formation:

(1) An A/S ratio, or ratio of mass of air added to (or released from) the system to mass of solids entering the flotation chamber.

(2) Recycle ratio, which defines the ratio of recycle flow (containing dissolved air) to influent flow rate to the flotation chamber.

(3) Suspended solids concentration in the flotation chamber.

A fourth factor requiring parameterization with respect to aggregate formation is the effectiveness of the chemical conversion processes initiated as a result of chemical addition. In order for a particle to be separated in the flotation process, it is necessary that the particle be destabilized with respect to electrical charge so that the particle can be floated in an air bubble-particle aggregate or settled by gravity. The jar test procedure was used in the present study, in addition to the results from the pilot-scale study, to evaluate the effectiveness of chemical conversion and selection of chemical doses or dose ranges to be used in the tests.

Selection of Control and Performance Variables

The control variables selected to characterize the performance of the Baker Street dissolved air flotation facility were as follows:

(1) Liquid loading rate to the flotation chamber (gpd/sq ft).

(2) Specific chemical dose (mg chemical/mg influent suspended solids).

(3) Influent suspended solids concentration to flotation chamber (mg/l).

Characterization

The input-output parameters used to characterize the performance of the Baker Street dissolved air flotation facility on dry-weather flow are illustrated in the flow sheet of Figure II-2 and the symbology is summarized in Appendix A. The input/output parameters have been combined with the process variables illustrated in Figure II-2 to develop the following working equations for process characterization with the plant:

(1) Total liquid loading rate to flotator:

$$LLR_T = (Q_I + Q_R)/A \qquad \text{(II-1)}$$

where: LLR_T = total liquid loading rate (gpd/sq ft)
Q_I = influent flow rate (gpd)
Q_R = recycle flow rate (gpd)
A = flotator surface area (sq ft)

(2) Feed TSS to flotator:

$$X^S = \frac{Q_I X_I^S + Q_R X_R^S}{Q_I + Q_R} \qquad \text{(II-2)}$$

where: X^S = total TSS concentration influent to flotator (mg/l)
X_I^S = TSS concentration in influent (mg/l)
X_R^S = TSS concentration in recycle (mg/l)

(3) Air/solids ratio:

$$A/S = 1.98 \times 10^4 \frac{Q_{AR}}{LLR_T X^S} \qquad \text{(II-3)}$$

where: A/S = air-solids ratio based on dissolved air released (lb air/lb solids)
Q_{AR} = dissolved air release rate (SCFM)

(4) Dissolved air release rate:

$$Q_{AR} = 12.4 X^{AR} Q_R \qquad \text{(II-4)}$$

where: X^{AR} = dissolved air released in recycle flow (lb/gal)

The procedure for determining X^{AR} is presented in Appendix B, *Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility*.

WET-WEATHER SIMULATION

The similarities in composition of dry-weather sanitary sewage and combined sewer overflows have been reported in previous studies. Combined sewage overflows from the Selby Street drainage basin in San Francisco characterized during 1967 (Reference 1) indicated a three-phased pollutant concentration-time profile that was described as follows:

(1) An initial phase in which the combined sewage quality was analogous to raw sanitary sewage;

(2) A second phase in which the constituent levels in the combined sewage increased above those of sanitary sewage due to factors such as system scouring; and

(3) A final phase in which combined sewage strength receded to that

of a dilute sanitary sewage.

Also, storms monitored at Baker Street in April 1969 (Reference 2) indicated peak pollutant concentrations greater than usually occur in domestic sewage that gradually decreased in concentration to levels typical of dilute sanitary sewage. From other studies (Reference 3) it has been stated that concentrations of pollutants in separated storm water runoff are not substantially different from those in raw sanitary sewage. In view of these observations, the use of dilute raw sewage or dry-weather sanitary flows to simulate performance of the dissolved air flotation process under wet-weather conditions was considered reasonable and justifiable.

EXPERIMENTAL APPROACH

The general objective of the experimental approach was to document the process performance curves or the multidimensional response surface postulated for the dissolved air flotation process. Dissolved air flotation performance in the present study was viewed primarily in terms of suspended solids removal efficiency, and secondarily in terms of removal efficiencies for other wastewater constituents of specific interest in terms of receiving environment quality.

The prototype plant operations consisted of two levels of inquiry: laboratory-scale jar testing; and plant-scale continuous run tests. The jar test program was used to test on a simulation basis the efficacy of alternative chemical treatment systems to achieve chemical conversion, the efficacy of the treatment being based on the separation achieved during a settling period in the containers used in the test. The jar test program was conducted as an on-going support test paralleling the continuous run tests with the prototype plant to provide a basis for predicting or confirming the appropriate chemical treatment system (dose, pH, etc.) to be used in the subsequent prototype testing.

The specific objective of the continuous run program was to establish the combination of process variables at which maximum process efficiency is obtained. A total of 16 continuous run tests were made to examine

process efficiency using the range of variables indicated in Table II-1. The number of point observations (operations with a single set of process variables) used to define each response surface was based upon the postulated shape of each curve. Information on each point observation was generated by a single continuous run in which each continuous run was defined as a time period of prototype plant operation during which an effluent of stable, acceptable quality characteristics was obtained.

TABLE II-1

OVERVIEW OF CONTINUOUS RUN SETS IN PROTOTYPE DRY-WEATHER OPERATIONS

Variable	Range	Units
Specific alum dose	0 - 15	mg/mg influent TSS
Liquid loading rate	2,678 - 4,820	gpd/sq ft
Air/solids ratio	0.02- 0.50	lb air/lb TSS
Specific polymer dose	0 - 0.15	mg/mg influent TSS
Alum/polymer combinations	0-1.5, 0-0.1	mg/mg influent TSS

NOTES: (1) A constant skimmer system flight travel rate of 2.0 ft/min was used in all runs.

(2) The scum pipe was set for continuous operation with the front skimming depth at 2 in. and the back skimming depth at 1 in.

FIGURE II-1

FLOW SHEET FOR DISSOLVED AIR FLOTATION PROCESS

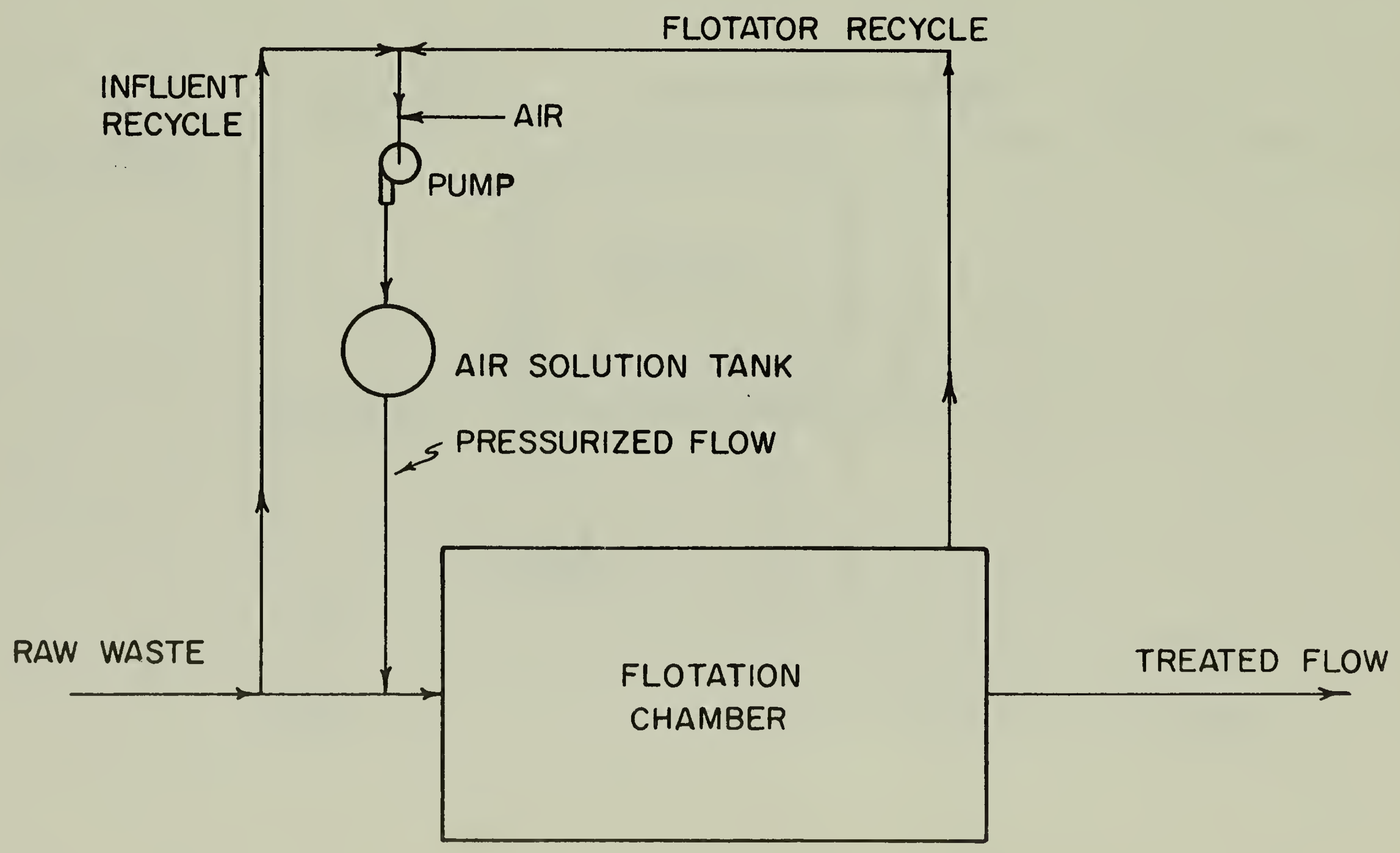
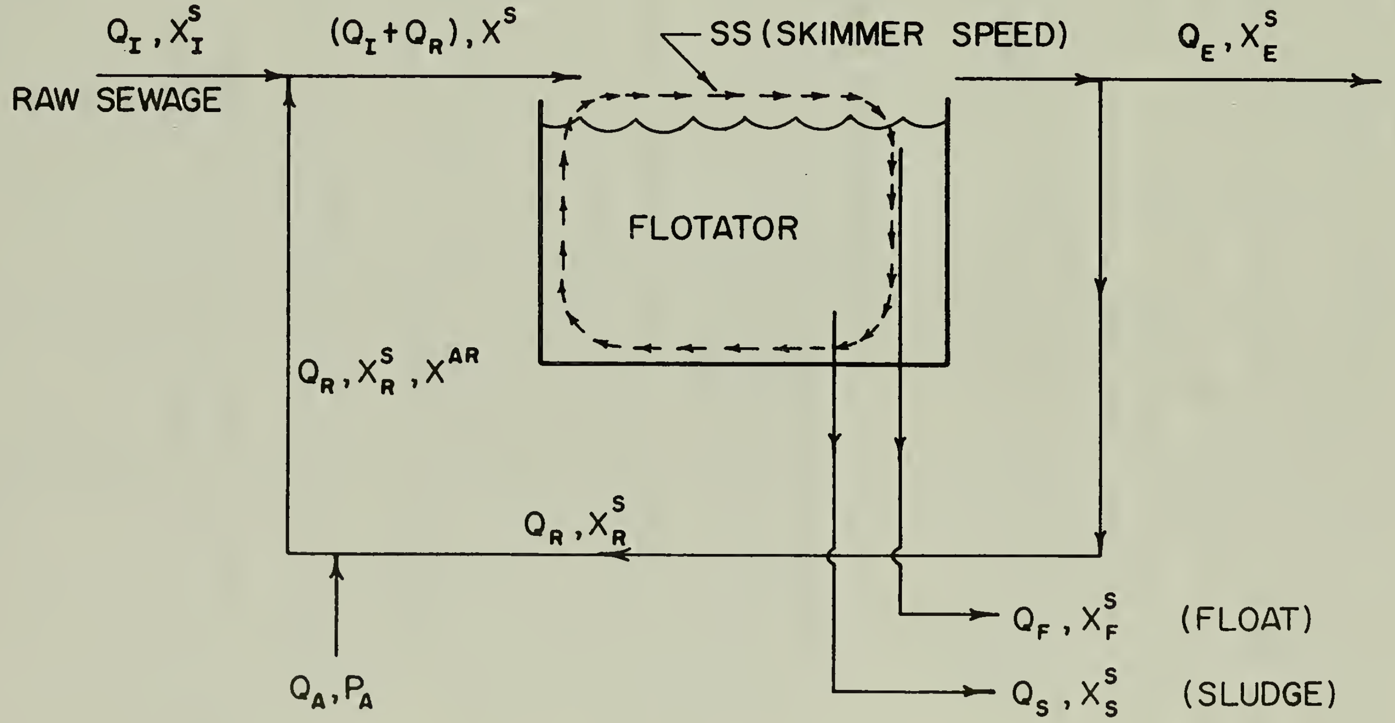


FIGURE II-2

FLOW SHEET FOR CHARACTERIZATION OF PROTOTYPE PLANT OPERATIONS



CHAPTER III

EVALUATION PROGRAM

Prototype testing was conducted at the Baker Street dissolved air flotation facility, located at the northwest corner of the Marina Green in San Francisco. Figure III-1 is a location map showing the facility, the 108-in. diameter outfall serving the facility, and the sewerage system immediately upstream from the plant at the intersection of Baker Street and Marina Boulevard. The Baker Street combined sewer receives the dry-weather flow of a population of 14,500 people including 7,000 persons in the Presidio, and the wet-weather storm runoff from the 167-acre Baker Street drainage area. The peak storm runoff rate for a five-year storm from the Baker Street drainage area is about 150 mgd.

DESCRIPTION OF BAKER STREET FACILITY

A partial process flow sheet for the Baker Street facility is presented in Figure III-2 and the principal characteristics and components of the facility are listed in Table III-1. The hydraulic capacity of the entire treatment facility is 24 mgd and the capacity of the influent structure and outfall is 160 mgd, sufficient to accommodate the runoff from a five-year storm. The treatment facility is comprised of two modules each of 12 mgd capacity and each capable of operation independent of the other. As noted in Figure III-2 and Table III-1, each module has the following key components:

(1) Flotation tank, designed at a nominal surface loading rate of 6,000 gpd/sq ft and equipped with sludge and scum removal systems.

(2) Recycle system, with pumping capacity rated at 2.4 mgd (or 20 percent of the maximum influent flow rate), piping to permit intake of recycle flow from either the flotation tank at a point just under the effluent launder or from the raw influent stream. The recycle system includes a two-stage centrifugal pump, retention tank, and four pressure reducing valves (one for each of the four flotation cells in each tank).

(3) Chemical feed systems for handling alum, caustic, polyelectrolyte, and sodium hypochlorite solutions.

TABLE III-1

PRINCIPAL CHARACTERISTICS AND COMPONENTS OF BAKER STREET DISSOLVED AIR FLOTATION FACILITY

Sector	Item	Description
Hydraulic	Treatment capacity	24 mgd total; 12 mgd per flotation tank (2) or 3 mgd per flotation cell (8)
	Influent/Effluent	160 mgd; 24 mgd treated flow and 136 mgd bypass
Flotation Cells	Overflow rate	6,000 gpd/sq ft
	Volume	52,000 gal/cell or 210,000 gal per tank
	Detention time	25 minutes
	Weir loading rate	75,000 gpd/ft at 6,000 gpd/sq ft overflow rate
	Flight speed	2 fpm
	Sludge removed	Screw conveyor: 5, 10, 15 rpm variable; 100 gpm maximum
	Skimmer system	Front skimming depth, 0-2 in.; back skimming depth 0-1 in.; 3/4-min skimming cycle per 0 to 30 min intervals
Recycle System	Recycle pumps	One two-stage centrifugal pump per tank at 2.4 mgd each rated capacity
	Retention tank	One per tank at 150 cu ft each, or 74 sec hydraulic residence time
	Air supply	One compressor per tank rated at 26 SCFM each at 65 psi; actual available supply 10 to 13 SCFM per tank

TABLE III-1 (Cont'd)

PRINCIPAL CHARACTERISTICS AND COMPONENTS OF BAKER STREET DISSOLVED AIR FLOTATION FACILITY

Sector	Item	Description
Chemical Feed System	Alum solution	36°Be, 36.5% $Al_2(SO_4)_3$
	Alum storage	One 2,700 gal tank
	Alum feed rate	One pump variable to 250 gph maximum
	Caustic solution	30% caustic, 39.9% NaOH
	Caustic storage	One 700 gal tank
	Caustic feed rate	One pump variable to 100 gph maximum
	Polyelectrolyte solution	Dow Purifloc C-31, 50,800 mg/l
	Polyelectrolyte storage	One 1,300 gal tank
	Polyelectrolyte feed rate	One pump per tank, each variable to 110 gph maximum
	Hypochlorite solution	14% available Cl_2
	Hypochlorite storage	One 3,600 gal tank
	Hypochlorite feed rate	One pump per tank, each variable to 75 gph maximum
Solids Handling System	Air lift pump	One pump per tank for transfer of settled solids to solids sump; air consumption to est. 3 SCFM maximum
	Solids sump pump	One pump variable to 550 gpm maximum

(4) Solids handling system, providing for the air-lifting of settled solids and gravity flow of floated solids to a common solids sump for both modules and for the ultimate transfer of material from the solids sump to the Marina Pumping Station.

The control system of the facility provides for the fully automatic startup of the module selected for initial filling and for sequential automatic startup of the other module after a preset flow rate is attained in the first module.

For this demonstration program three of the four cells in each of the flotation tanks were isolated at the influent piping, recycle flow piping, and effluent launders, so that only the most southerly flotation cell of each tank could be put into operation. A 12-point sampling grid is located in each of the most southerly flotation cells.

OPERATING AND MONITORING PROCEDURES

Flow to Flotation Facility

Dry-weather flows (raw sanitary sewage) from the Baker Street drainage basin were collected and transported to a diversion structure located at Marina Boulevard and Baker Street, as shown in Figure III-1, at which point flow is intercepted and transported to the Marina Pumping Station and thence to the North Point treatment plant. The inaccessible diversion structure is a 5-ft diameter tunnel with a side-flow weir leading to the flotation plant. During wet-weather conditions, flows from the Baker Street drainage basin exceed the capacity of the Marina Pumping Station, resulting in the overflow of a portion of combined sewage to the prototype plant.

To divert dry-weather flow from the Baker Street drainage basin to the dissolved air flotation facility, a metal shear gate was installed at the manhole located on Marina Boulevard about 200-ft east of the diversion structure at Baker Street and Marina Boulevard, as shown in Figure III-3. Flow to the Marina Pump Station from the Baker Street drainage area was virtually stopped with a resulting buildup of wastewater head at the shear-gate manhole. A reservoir was formed between this manhole along the 21-in. diameter sewer and the overflow structure at Baker Street and Marina Boulevard.

To augment the dry-weather flow, which was in the order of 1 mgd, a diesel driven variable-speed trash pump, rated at 1,500 gpm, was installed to pump from the westerly tank, as shown schematically in Figure III-4. The procedure used to augment flow was to:

(1) Fill the west flotation tank (approximately 210,000 gal) with raw sewage, and to mix with its recycle pump.

(2) Obtain sufficient hydraulic head from the normal dry-weather flow in the influent sewer to begin testing in the southerly cell of the east flotator.

(3) Throttle butterfly valve to the east flotator to obtain desired flow rate.

(4) Startup and throttle trash pump as needed to maintain desired flow rate.

Using this procedure influent flow rates could be maintained up to 2.5 mgd within 5 percent variation over a period of several hours.

Influent Characteristics

In order for the dissolved air flotation plant to discharge effluent, a sufficient hydraulic head must be developed in the sewer tributary to the plant to cause an overflow from the flotation tank. It is estimated that 150,000 gal of wastewater must be accumulated upstream of the diversion structure at Marina Boulevard and Baker Street and 220,000 gal of wastewater accumulated downstream of the diversion, including the plant inlet structure, for there to be a discharge from the plant. This amount of storage or detention could have a significant effect upon the quality characteristics of the dry-weather flow influent to the plant. For example, at a flow rate through the system of 1.0 mgd, the detention time in the influent works would be over six hours. This is significantly above conventional detention times used for primary sedimentation treatment. Therefore it can be postulated that the quality of influent at the rate of 1.0 mgd to the prototype plant might more resemble the quality of effluent from a primary treatment plant than that of raw domestic sewage. The impact of these factors on the results of the dry-weather test program will be discussed in Chapter IV.

Continuous Run Tests

The protocol for the continuous run tests consisted of the following steps:

(1) All process control variables Q_l, specific chemical doses, A/S, and skimmer system were set at the desired level. A summary of equipment settings is presented in Table III-2.

(2) In parallel with Step 1, influent and effluent homogenized-sample turbidity levels were monitored at 15-min intervals until a stable effluent quality was achieved for at least a 30-min interval (*i.e.*, less than 10 percent change in effluent homogenized-sample turbidity levels over a 30-min period).

(3) In parallel with Steps 1 and 2, the influent flow rate was monitored and the plant butterfly valves and/or the trash pump adjusted to maintain the desired flow rate. Additionally the chemical dosage rate was adjusted, on the basis of turbidity measurements, to maintain a constant dosage based on TSS levels.

Steps 1 to 3 invariably required one to two hours of effort to achieve the desired prototype plant effluent quality (under varying conditions of influent raw sewage quality), a stable effluent quality, and the desired specific chemical dose and pH level.

When the control variables of the plant had been adjusted, it was then possible to proceed to the continuous run monitoring program, which consisted of the following:

(1) A time clock was started to provide a common reference for recording all operating and monitoring activities during the run.

(2) The contents of the float/sludge hopper was sampled at 15-min intervals to form a composite sample during the run.

(3) A dissolved air release measurement was initiated at the start of the run and conducted during the run according to the procedure outlined in Appendix B of Appendix C, *Measurement of Dissolved Air Release.*

(4) At least four sets of influent and effluent samples were taken

TABLE III-2

SUMMARY OF CONTROL AND EQUIPMENT SETTINGS FOR PROTOTYPE STUDIES

Setting	Operations Without Chemicals	Operations With Chemicals
Tank selector	East	East
Adj. time delay-opening gate to other tank	5 min	5 min
Flow controller-east	Set at desired flow rate	Set at desired flow rate
Flow controller-west	Set at desired flow	Set at desired flow
Bypass gate flow controller	24 mgd	24 mgd
Skimmer system-east		
• Front skimming depth	2 inch	2 inch
• Back skimming depth	1 inch	1 inch
• Time interval between skimming cycles	Continuous operation	Continuous operation
Selector for alum & caustic feeding to:	-	East
Alum		
• feed to	-	2nd stage pump inlet
• manual control setting		Variable
Caustic		
• feed to	-	1st stage pump bowl
• manual control setting		Variable
Polymer-east		
• feed to	-	12" ϕ pressure line or 36" ϕ influent line
• manual control setting		Variable
Polymer-west		
• feed to	-	-
• manual control setting	-	-
NaOCl-east		
• feed to	-	36" ϕ influent line
• manual control setting	-	Variable
NaOCl-west		
• feed to	-	-
• manual control setting	-	-

NOTE: (1) 80% NaOCl setting equivalent to trial dose of 20 mg/l at 12 mgd flow.

at 10-min intervals during the run and analyzed for homogenized-sample turbidity. The results of the influent sample analysis were used to guide the adjustment of the chemical dosage system; the results of the effluent sample analyses were used to track the stability of effluent quality. The monitoring was continued at 10-min intervals until three consecutive effluent quality determinations meeting the 10-percent criterion were obtained.

(5) At the time when the effluent quality criterion was met:

(a) Compositing of the float/sludge samples was stopped and aliquots of float/sludge composites were analyzed in accord with the schedule in Table III-3.

(b) The dissolved air release measurement was terminated.

(c) Influent and effluent samples were taken and analyzed for the schedule presented in Table III-3.

(6) The prototype plant system was then either prepared for the next continuous run or shut down.

Analytical Procedures

The schedule of analyses presented in Table III-3 was done using procedures presented in ***Standard Methods*** (Reference 4) with the following exceptions:

(1) Floatables and HEM (oil and grease) were done according to procedures developed by Engineering-Science, Inc. (Reference 5).

(2) Homogenized-sample turbidity was done using a Hach Model 1860 Turbidimeter and a standardized sample homogenization procedure prior to analysis. Sample homogenization was done to normalize the particle size distributions in the sample prior to the turbidity analysis.

The suspended solids-turbidity correlation shown in Figure III-5 was used in the present study to convert homogenized sample turbidity levels to TSS values. The correlation was developed in the pilot plant study (Appendix C) and confirmed by results of samples from the prototype operation.

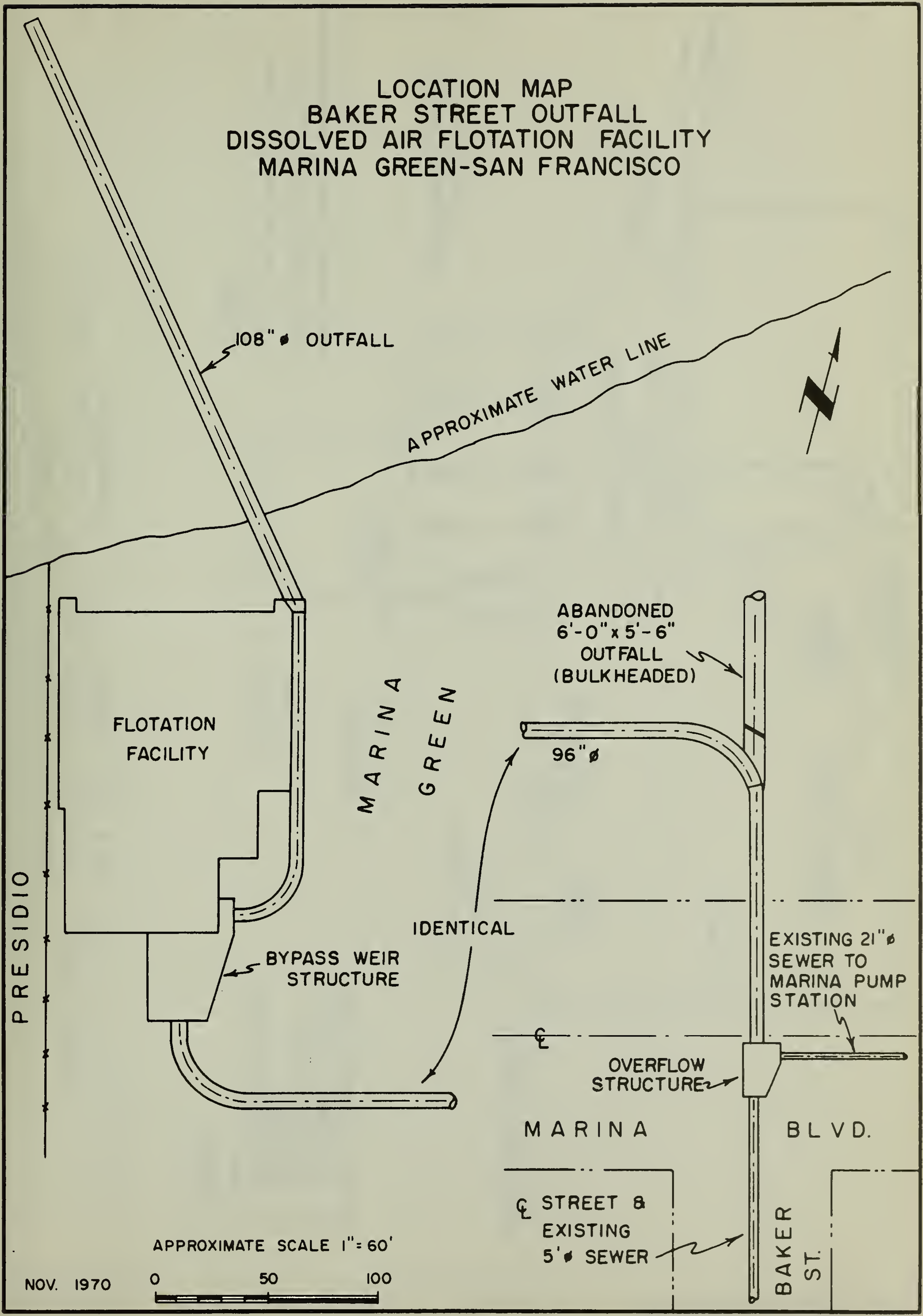
TABLE III-3

SCHEDULE OF ANALYSES

Characteristics	Sampling Location				
	Facility Influent	Facility Effluent	Flotation Cell (12)	Float/ Solids	Recycle
COD	✓	✓			
BOD*	✓	✓			
Floatables	✓	✓		✓	
Oil & Grease (HEM)	✓	✓		✓	
Settleable Solids*	✓	✓			
Nitrogen Forms	✓	✓		✓	
O-Phosphate	✓	✓		✓	
TSS	✓	✓	✓	✓	✓
VSS	✓	✓		✓	
Alkalinity	✓	✓			
Total Coliform MPN*	✓	✓			
Fecal Coliform MPN*	✓	✓			
Cl_2 Residual*		✓			
Toxicity	✓	✓			
pH	✓	✓			
Color	✓	✓			
Turbidity*	✓	✓			

NOTE: *Analysis made or setup in field.

FIGURE III-1



LOCATION MAP
BAKER STREET OUTFALL
DISSOLVED AIR FLOTATION FACILITY
MARINA GREEN-SAN FRANCISCO

ENGINEERING-SCIENCE, INC.

FIGURE III-2

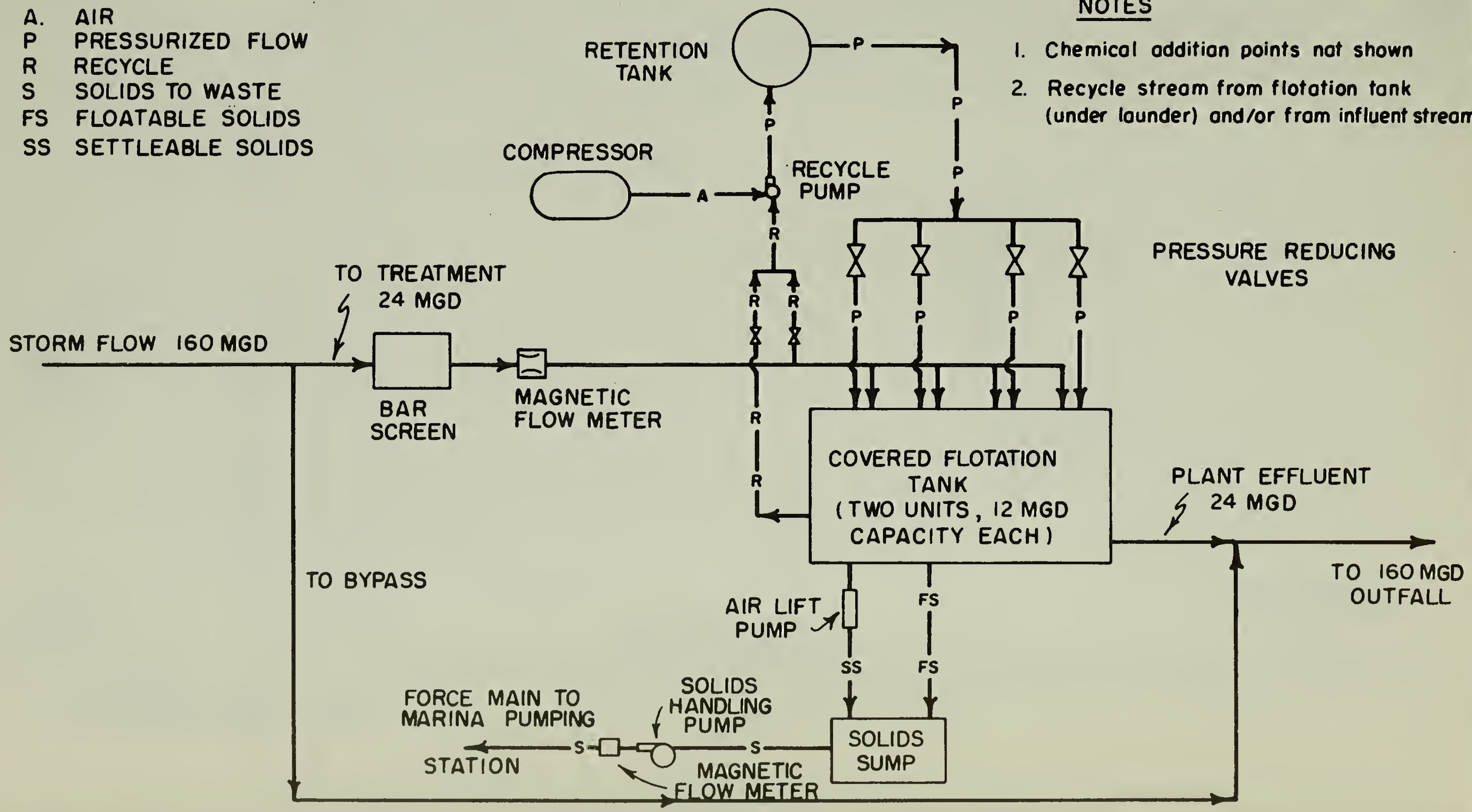
SIMPLIFIED PROCESS FLOW SHEET
BAKER STREET OUTFALL DISSOLVED AIR FLOTATION FACILITY
CITY AND COUNTY OF SAN FRANCISCO

LEGEND

A.	AIR
P	PRESSURIZED FLOW
R	RECYCLE
S	SOLIDS TO WASTE
FS	FLOATABLE SOLIDS
SS	SETTLEABLE SOLIDS

NOTES

1. Chemical addition points not shown
2. Recycle stream from flotation tank (under launder) and/or from influent stream



ENGINEERING-SCIENCE, INC.

FIGURE III-3

PLAN SHOWING SHEAR-GATE LOCATION FOR DISSOLVED AIR FLOTATION DRY WEATHER STUDY PROGRAM

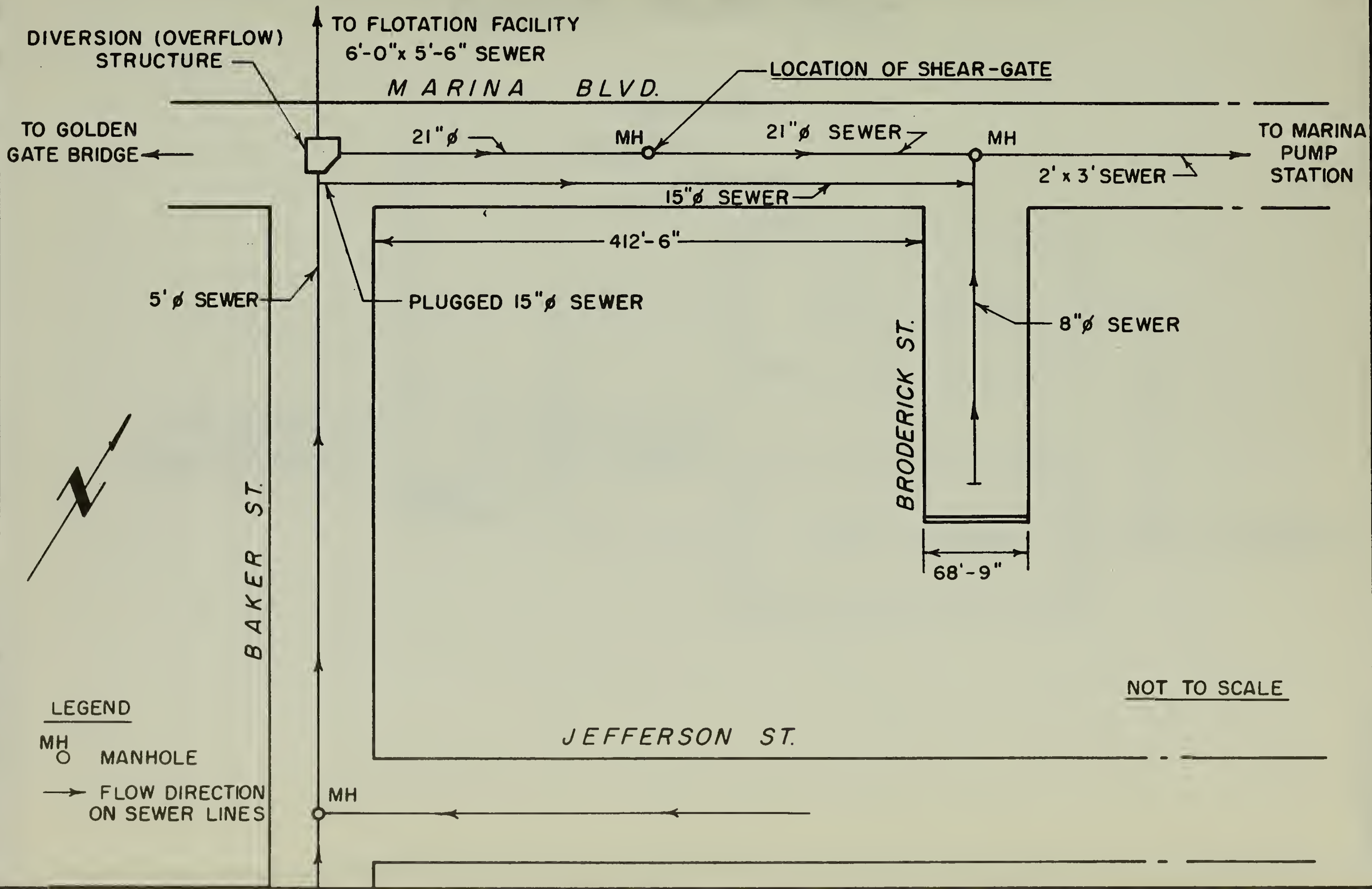


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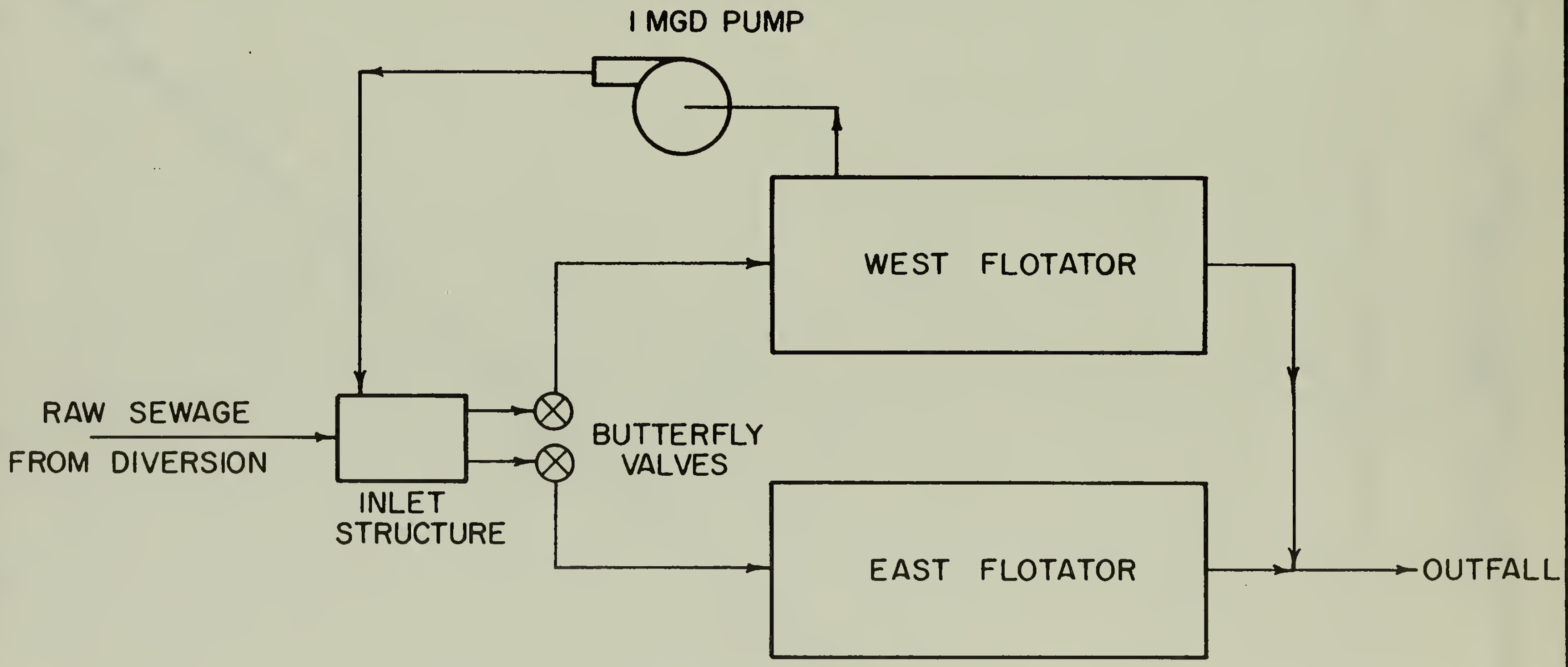
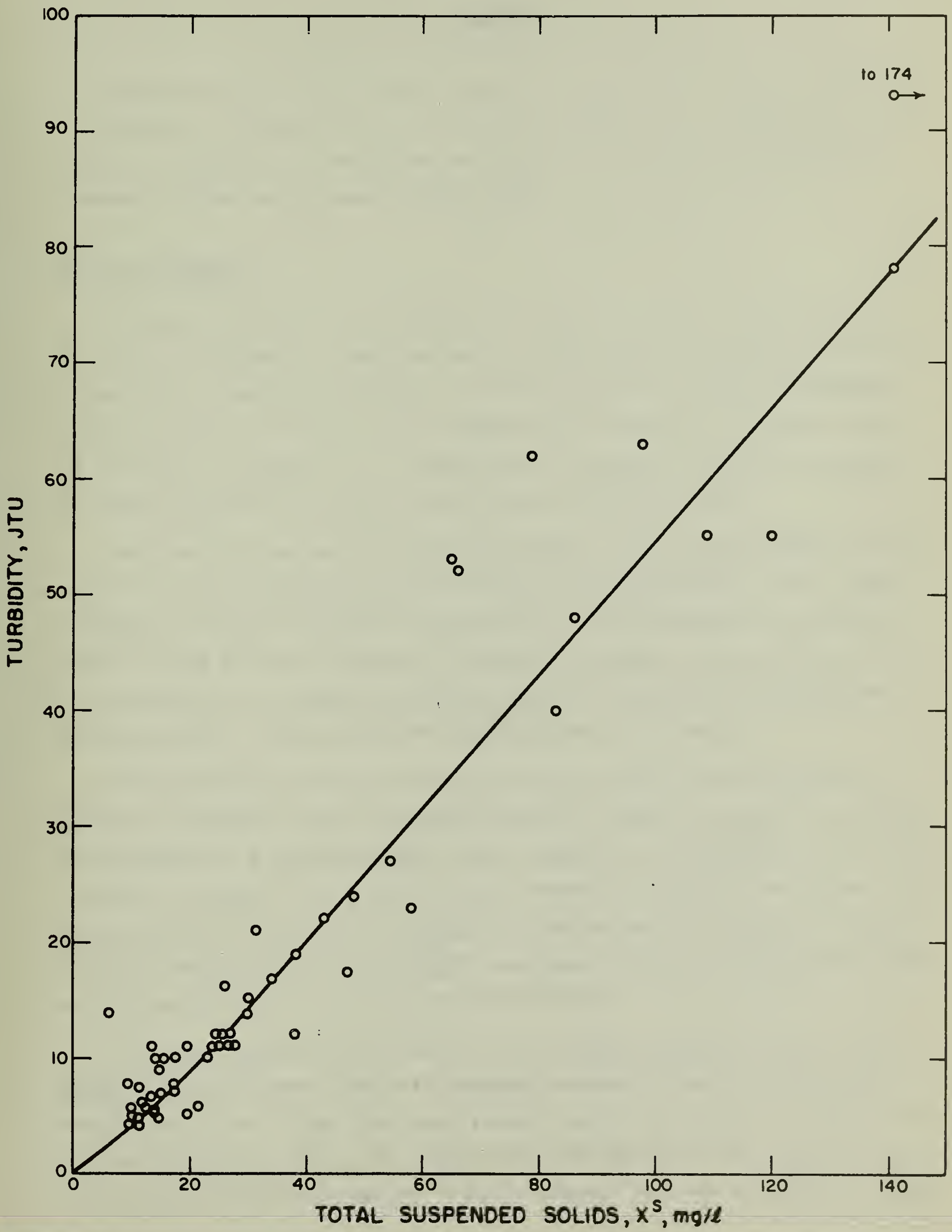
FIGURE III-4

PROTOTYPE INFLUENT SYSTEM



ENGINEERING-SCIENCE, INC.

SUSPENDED SOLIDS-TURBIDITY RELATIONSHIP FOR HOMOGENIZED SAMPLES



CHAPTER IV

RESULTS

The results of the jar test program are presented first in order in this chapter, although the jar testing was conducted throughout the continuous run tests as a basis for selecting or confirming the chemical treatment system to be used in each case.

JAR TEST PROGRAM

The jar test results developed with alum or polymer individually and alum and polymer in combination are summarized in graphical form in Figure IV-1. Over 30 individual jar tests were run using raw sewages containing 70 to 110 mg/l TSS as measured by turbidity, and each data point shown in Figure IV-1 is identified in terms of turbidity removal efficiency and the final pH of the liquid in the jar test.

The dose ranges selected for evaluation in the test program varied from 0 to 3 mg alum/mg TSS and 0 to 0.6 mg polymer/mg TSS. The ranges of chemical doses presented an opportunity for evaluating the relative merits of the different chemical treatment systems, and provided a base of information for comparing optimal jar test results with the corresponding optimal results obtained in continuous run tests.

An evaluation of the results of the jar tests done with polymer alone has indicated that a maximum turbidity removal of about 60 percent was obtained at a specific dose of 0.5 mg/mg TSS, as compared with about 15 percent removal in the control test where no chemicals were used. The optimal specific dose of 0.5 mg/mg TSS (equivalent to a dose of 50 mg/l at a TSS concentration of 100 mg/l) was about the same (0.35 mg/mg TSS) as that observed during the pilot plant study.

Turbidity removals observed at alum dosages ranging from 0 to 3.0 mg/mg TSS and polymer (DOW C-31) dosages between 0 and 0.13 mg/mg TSS were averaged for fixed alum dose levels and are presented in Table IV-1. For jar tests conducted with alum alone, average turbidity removal efficiencies increased rapidly from 15 percent with no alum to a maximum

TABLE IV-1

EFFECT OF ALUM AND ALUM-POLYMER ON AVERAGE TURBIDITY REMOVAL EFFICIENCY

Alum Dose mg/mg	Average Turbidity Removal (%)	
	Alum	Alum-Polymer*
0	15	-
0.5	95	68
1.0	86	86
1.5	80	86
2.0	81	92
2.5	82	93
3.0	89	96

*Polymer dosages less than 0.15 mg/mg TSS

observed removal of 95 percent at an alum dosage of 0.5 mg/mg TSS. As alum dose levels were increased further, a gradual decrease in removal efficiency to an intermediate minimum of 80 percent at 1.5 mg/mg TSS was observed, followed by an increase to 89 percent at 3.0 mg/mg TSS.

When alum and polymer were used in combination, increasing average turbidity removal efficiencies were noted with increasing alum dose levels, reaching a maximum of 96 percent at the highest alum dose employed (3.0 mg/mg TSS).

Based on the limited jar test data presented in Figure IV-1, it appears that the combined use of alum and polymer in the range of alum dosages between 1.0 and 3.0 mg/mg TSS and polymer dosages less than 0.13 mg/mg TSS offers an advantage over the use of alum alone, in terms of enhanced turbidity removal.

It is evident from the jar test results that: (1) alum alone is effective for removing turbidity in excess of 80 percent over a broad dose range; (2) maximum turbidity removal of 60 percent was achieved with polymer in a narrow dose range at about 0.5 mg/mg TSS; and (3) improved turbidity removals at the larger alum dosages were obtained in combination with small dosages of polymer.

CONTINUOUS RUNS

The basic information obtained in the 23 continuous run tests, with the exception of data from Runs 2, 4 through 10 which were obtained when the chemical pumps were inoperative, was analyzed using Equations II-2 to II-5. The results were evaluated to document the response surfaces for each process variable in terms of TSS removal efficiency and to ascertain the efficiency of dissolved air flotation for removal of other wastewater constituents.

Effect of Chemical Doses

Alum

The relationship between specific alum dose and process efficiency is illustrated by the data in Figure IV-2. The values of R_R, LLR_T, A/S, and X^S for the runs included in the analysis are listed in the figure.

The values of R_R vary from a low of almost 70 to about 122 percent, a range in which process efficiency remains fairly stable (Figure IV-6, Appendix C, ***Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process--A Pilot Plant Study***). The total liquid loading rate is nearly constant for runs CR-11, CR-12, and CR-13, at just over 3,000 gpd/sq ft for runs CR-1 and CR-3. However, for CR-1 and CR-3, in which the A/S ratio was the same, the difference in removal efficiencies can be attributed to alum addition in CR-1, whereas CR-3 was conducted with no alum. All the values of A/S were above the critical value of 0.02 lb air/lb TSS (Figure IV-7, Appendix C, ***Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process--A Pilot Plant Study***), below which there is not enough dissolved air in the recycle flow to induce flotation in the flotator.

Process efficiency, as measured by turbidity removal, was found to increase from 14 percent at no alum addition to a peak removal efficiency of near 65 percent at an alum dosage of 6 mg/mg TSS.

It is apparent from the relationship shown in Figure IV-2 that with increasing alum dosage process efficiency increases to a saturation level at an alum dose of about 6.0 mg/mg TSS, and remains essentially stable thereafter with increasing alum doses. The stability of process efficiency over a wide range of alum doses is a desirable characteristic of dissolved air flotation treatment using alum for two reasons:

(1) Less operator judgment and control capacity are required to maintain the specific alum dose (and pH) in the desired range.

(2) It is possible to achieve a stability of process performance under a wide range of influent solids loadings such as typically experienced in treatment of combined sewage and raw sanitary sewage.

Polymer (C-31)

The relationship between process efficiency and specific polymer dose is illustrated by the data listed and presented in Figure IV-3. The polymer doses selected for continuous runs (0.04 to 0.15 mg/mg TSS) were within the range of polymer doses typically used in waste treatment applications, but below the polymer dose (0.5 mg/mg TSS) at which

maximum solids removals were obtained in the jar tests.

The response surface of Figure IV-3 shows an optimal turbidity removal at a polymer dose of 0.06 mg/mg TSS. This optimal removal (10 percent) is only slightly higher, however, than the continuous run without polymer addition (9 percent). Also, suspended solids removal efficiencies decreased to near zero as polymer dosages were increased above 0.15 mg/mg TSS. Thus for the polymer doses tested under continuous conditions in this study, no improvement in suspended solids removal efficiency was observed by the use of polymer alone.

Effect of Process Variables

Total Liquid Loading Rate (LLR_T)

The relationship between process efficiency and LLR_T in the dissolved air flotation process is illustrated by the data shown in Figure IV-4. The values of A/S, R_R, and X^S for the runs included in the analysis are also listed in the figure. Four runs were conducted at an alum dosage very near 2.5 mg/mg TSS and were used to establish the shape of the response surface. However, since suspended solids removal efficiencies were relatively low at these dosages (see Figure IV-2), single data points and the derived relationship values at higher alum dosages are included on Figure IV-4 to indicate expected removals as a function of alum dose level.

The response surface of Figure IV-4 at an average alum dosage of 2.45 mg/mg TSS defines a relationship in which process efficiency decreases at a gradually decreasing rate with increasing LLR_T from an efficiency of 30 percent at an LLR_T of 3,200 gpd/sq ft to about 15 percent at an LLR_T of 4,600 gpd/sq ft at a higher LLR_T of 4,820 gpd/sq ft with an alum dosage of 5.2 mg/mg TSS, the relationship presented in Figure IV-2 indicated a suspended solids removal of 60 percent (76 percent was actually measured). A decrease in process efficiency was observed (Figure IV-2) at an alum dose of 13.8 mg/mg TSS. This is believed to be a consequence of the escape of alum flocs into the effluent at such high alum dosage and a possible encroachment with the region of peptization.

The decrease in process efficiency as surface loading is increased may be associated with one or more of the following factors:

(1) Destruction of air bubble-particle aggregates in the inlet structure with increasing hydraulic loading to the flotation chamber.

(2) Hydraulic overloading of the effluent launders.

(3) Breakup of float by turbulence within the liquid in the flotation tank.

(4) Hydraulic short circuiting in the flotator.

Effect of Recycle:

The relationship between process efficiency and recycle ratio was not investigated in this study because flow control in the two-stage constant-rate recycle pump was not feasible within the period of the test program. Two runs (CR-16 and CR-21) were conducted to assess the impact of recycle mode on process efficiency. The process variable for these two runs did not vary by more than 10 percent except that in Run CR-16, flotator recycle was used and in Run CR-21, influent recycle mode was used. The turbidity removal efficiency differed by only four percent between the two recycle modes.

Effect of Air/Solids Ratio

The relationship between process efficiency and air/solids ratio in the dissolved air flotation process is shown by the data presented in Figure IV-5. The values of process variables (other than A/S) used in the runs selected for the analysis were within ranges of the individual parameters in which process efficiency was not affected significantly by the variations among these process variables.

The response surface for A/S is characterized by a rapid increase in process efficiency from zero at an A/S ratio of 0.02 lb air/lb TSS to an excess of 30 percent at an A/S ratio of 0.5, The saturation characteristics of the A/S response surface were observed also in the pilot-plant investigation (Figure IV-7, Appendix C, *Treatment of Raw and Dilute Raw Sewage with the Dissolved Air Flotation Process--A Pilot Plant Study*).

Effluent Quality Characteristics

Information developed on the settleable solids, HEM, floatable

materials, total and fecal coliform characteristics of dissolved air flotation process effluents in all the continuous runs is summarized in Table IV-2. Data describing the nitrogen forms, orthophosphate, color, BOD, COD, and toxicity characteristics of the dissolved air flotation effluents in selected runs are presented in Table IV-3. For purposes of comparison, the average values of effluent concentration and removal efficiency for each characteristic have been computed from grouped results for the runs conducted with each chemical.

The settleable solids concentrations in the influent and effluent were generally very low, making the detection of removal efficiency difficult with the standard settleable solids test. The removal efficiency in the alum runs averaged nearly 48 percent, which includes CR-II in which the high dosage of alum used caused an effluent settleable solids of 15 ml/l/hr. The use of alum with polymer and polymer alone produced no removal of settleable solids.

The HEM (oil and grease) removal efficiency with alum was 46 percent as compared to 20 percent with alum-polymer and 9 percent with polymer alone. The removal efficiency of floatable materials averaged 97.5 percent for the alum runs, 98.5 percent for the polymer runs, and 100 percent for the runs with alum and polymer in combination.

The efficiency of total nitrogen removal in the alum runs (Table IV-3) was 22 percent and was higher than the removal with polymer (17 percent) or alum and polymer in combination (14 percent). An average of over 80 percent removal of orthophosphate was observed in both the alum runs and the runs with alum and polymer which was nearly twice the removal achieved with polymer alone; the difference being attributable to the effectiveness of alum for converting soluble phosphorus to a form separable by flotation. The efficiency of removal of color was over 70 percent in the alum runs as compared with 60 percent in the alum with polymer runs and 47 percent in the polymer runs. The efficiency of BOD removal was nearly equal at 50 percent in both the alum and the alum with polymer runs and slightly lower (43 percent) in the polymer runs. COD removal was 32 percent in the alum runs, 50 percent in the alum with polymer runs and 64 percent in the polymer runs.

TABLE IV-2

SUMMARY OF PERFORMANCE CHARACTERISTICS

Run	Settleable Solids		HEM (Oil & Grease)		Floatables		Total Coliforms (MPN/100 ml)		Fecal Coliforms (MPN/100 ml)	
	Effluent (ml/l/hr)	Removal (%)	Effluent (mg/l)	Removal (%)	Effluent[1] (mg/l)	Removal (%)	Influent	Effluent	Influent	Effluent
CR-1	<0.1	93.5	12.7	31.0	0.034	90	-	-	-	-
CR-3	<0.1	50.0	-	-	-	-	-	-	-	-
CR-11	15.0	0.0	3.8	33.4	-	-	4.3×10^7	<30	1.1×10^6	<30
CR-12	-	-	3.3	56.0	(0.13)	100	4.6×10^8	<30	7.5×10^7	<30
CR-13	0.1	50.0	4.6	63.2	(0.17)	100	-	-	-	-
CR-14	0.1	50.0	17.5	39.3	(0.28)	100	4.6×10^8	2.1×10^4	2.4×10^8	2.1×10^4
CR-15	-	-	21.3	4.1	(0.07)	100	-	-	-	-
CR-16	0.1	0.0	11.6	11.4	(<0.01)	100	1.5×10^8	2.4×10^5	9.3×10^7	2.4×10^5
CR-17	-	-	23.9	0.0	(0.17)	100	2.4×10^9	90	2.4×10^9	90
CR-18	0.1	0.0	13.1	20.3	(0.01)	100	9.3×10^7	150	2.3×10^7	90
CR-19	0.1	0.0	5.7	62.0	0.04	97	4.3×10^7	9.3×10^3	4.3×10^7	9.3×10^3
CR-20	-	-	26.3	0.0	-	-	2.4×10^8	9.3×10^3	2.4×10^8	9.3×10^3
CR-21	0.1	0.0	-	-	(0.57)	100	4.3×10^7	2.4×10^5	4.3×10^7	2.4×10^5
CR-22	<0.1	0.0	10.4	26.7	-	-	-	-	-	2.4×10^5
CR-23	<0.1	0.0	12.7	31.0	0.08	60	-	-	-	-
Average for run with Alum dose (1, 11, 12, 13)		47.7		45.9		97.5				
Average for run with Alum + Poly (18, 19)		0.0		20.3		98.5				
Average for run with Poly dose (17, 20, 22)		0.0		9.0		100				

[1] Values in brackets are influent concentrations.

TABLE IV-3

SUMMARY OF PERFORMANCE CHARACTERISTICS

Run	Total Nitrogen		Ortho-phosphate		Color		BOD		COD		Effluent Toxicity 96-hr Survival (%)
	Effluent (mg/l)	Removal (%)	Effluent (mg/l)	Removal (%)	Effluent (mg/l)	Removal (%)	Effluent (mg/l)	Removal (%)	Effluent (mg/l)	Removal (%)	
CR-1	19.9	13.5	4.45	49.9	18.0	64.0	114.0	13.5	138.9	20.0	-
CR-3	10.6	53.0	2.44	59.3	12.0	71.5	114.0	34.5	204.6	29.0	-
CR-11	12.9	43.0	-	-	2.0	95.0	58.0	58.0	-	-	-
CR-12	18.6	13.8	0.47	94.5	8.0	79.0	34.0	60.4	164.2	10.8	100
CR-13	19.5	15.8	<0.20	97.0	16.0	59.0	46.0	70.5	69.1	63.7	100
CR-14	18.5	4.8	<0.20	97.0	12.0	66.0	71.0	40.8	60.5	58.8	-
CR-15	13.3	0.0	<0.07	99.0	17.0	47.0	54.0	46.0	69.1	50.0	100
CR-16	17.0	21.6	0.19	96.0	17.0	37.0	53.0	51.0	95.0	62.0	100
CR-17	18.3	16.0	4.19	45.0	9.0	75.0	-	-	204.0	-	75
CR-18	17.0	28.6	0.90	86.6	4.0	89.5	58.0	50.9	205.0	22.4	49
CR-19	19.1	0.0	0.78	88.5	19.0	36.6	62.0	50.0	53.0	77.0	100
CR-20	20.1	-	-	-	-	-	51.0	53.6	202.0	-	100
CR-21	16.2	11.2	0.07	98.5	16.0	15.8	66.0	38.3	74.0	60.0	100
CR-22	20.1	17.6	3.14	43.4	22.0	18.8	57.0	32.2	66.0	64.4	100
CR-23	16.2	-	0.24	96.5	15.0	48.0	60.0	45.0	200.0	14.5	100
Average for Runs with Alum Only (1, 11, 12, 13)		21.5		80.3		74.2		50.6		31.5	100
Average for Runs with Alum & Poly (18, 19)		14.3		87.5		63.0		50.4		49.7	74.5
Average for Runs with Poly Only (17, 20, 22)		16.8		44.2		46.9		42.9		64.4	91.7

Effluent toxicity in the continuous runs was characterized using the 96-hr survival test. The survival of test organisms in the effluents was 100 percent in all but two of the runs tested. This is explained by difficulties encountered with the sodium hypochlorite feed pump rather than the differences in the chemical treatment. Therefore, effluents from the dissolved air flotation prototype plant during the dry weather test program were nontoxic.

Analyses for total coliform organisms were performed on the influent and effluent of the dissolved air flotation facility and in the receiving waters (Station 25 west of St. Francis Yatch Club) at flood tide during the dry-weather prototype studies. The data were analyzed and the distribution of the total coliform MPN data are presented in Figure IV-6. The log mean total coliform MPN concentrations in the influent, effluent, and receiving waters were, respectively, 1×10^8/100 ml, 1×10^3/100 ml, and 4×10^2/100 ml. These data show that a substantial decrease in coliform density were effected during the operation of the dry-weather studies.

Fecal coliform MPN in both influent and effluent streams of the dissolved air flotation were of the same order of magnitude as the total coliforms ranging from less than 30 MPN/100 ml to over 10^5 MPN/100 ml.

It is evident from the foregoing that alum was more effective than polymer for the chemical conversion of dissolved and colloidal materials to forms susceptible to separation by dissolved air flotation. Based on the relative effectiveness of alum and polymer in the dissolved air flotation process, it is concluded that alum is more effective than polymer when used for the dissolved air flotation treatment of raw sewage. However, treatment with alum and polymer in combination appears to be nearly as effective as treatment with alum alone.

Float and Sludge Characteristics

At the time of the dry-weather test program, there was no metering available on either the float or settled solids piping systems. These two waste streams were each conveyed individually to a common solids sump where they were sampled as a combined float/solids stream. A summary of the suspended solids and HEM characteristics of the float/solids sampled in each of the continuous runs (except those performed during chemical

pump malfunctioning) is presented in Table IV-4. The averages of the TSS and HEM characteristics have been computed for three groups of runs--runs with alum, runs with alum and polymer in combination, and runs dosed with only polymer as the chemical coagulant. The impact of the type of chemical treatment on the TSS concentration in the float/solids is indicated by the average TSS in the alum runs of over 500 mg/l. The average float/solids TSS in the runs with only polymer or in those runs with alum-polymer combinations was much lower than the average TSS in the runs with alum only. When polymer was used alone, average TSS was 17 percent, and when alum with polymer in combination were utilized, the average TSS was 25 percent of alum addition alone. The TSS levels in the float/solids varied from 38 to 1,384 mg/l, the HEM varied from 15 to 200 mg/l, and the total nitrogen varied from 12 to 56 mg/l. Because liquid loading rate did not vary substantially in these chemical dosage tests, dissolved air was above the threshold value in each test, and the other process variables remained essentially constant, it is concluded that the TSS concentration in the float/solids stream is greatly dependent on the type of chemical treatment.

TABLE IV-4

SUMMARY OF FLOAT/SOLIDS CHARACTERISTICS

Run	Chemical Used and Average Specific Dose (mg/mg TSS)		Float/Solids					
	Alum	Polymer	HEM (mg/l)	Total-N (mg/l)	NH_3-N (mg/l)	O-phosphate (mg/l)	Nitrate-N (mg/l)	TSS (mg/l)
CR-1	5.26	0.0	22.4	19.7	14.9	5.00	0.42	50
CR-3	0.00	0.0	-	12.9	4.99	2.21	-	92
CR-11	13.82	0.0	44.6	-	-	-	-	1,384
CR-12	1.60	0.0	43.0	20.0	12.30	0.34	0.03	220
CR-13	2.72	0.0	66.9	29.0	12.40	<0.20	0.37	232
CR-14	2.42	0.0	19.1	23.1	14.5	<0.20	0.10	88
CR-15	2.89	0.0	18.9	18.9	13.1	<0.07	0.04	40
CR-16	2.38	0.0	200.0	56.3	16.5	0.05	<0.02	38
CR-17	0.0	0.064	89.3	31.9	15.6	0.55	0.03	190
CR-18	1.158	0.080	-	28.7	13.1	0.29	<0.02	152
CR-19	1.226	0.055	21.8	22.2	15.9	0.78	<0.02	136
CR-20	0.0	0.155	33.8	-	-	-	-	36
CR-21	2.42	0.00	-	21.7	14.7	0.36	<0.02	94
CR-22	0.0	0.041	15.4	20.4	16.2	1.78	<0.02	68
CR-23	2.26	0.0	25.0	-	17.5	0.17	<0.02	176
Average for runs with Alum dose (1, 11, 12, 13)			44.2	22.9	13.2	1.84	0.270	584
Average for runs with Alum + Poly dose (18, 19)			21.8	25.4	14.50	0.53	<0.020	144
Average for runs with Poly dose (17, 20, 22)			49.5	26.1	15.90	1.16	0.025	98

EFFECT OF ALUM AND POLYMER ON EFFICIENCY OF TURBIDITY REMOVAL - JAR TEST PROGRAM

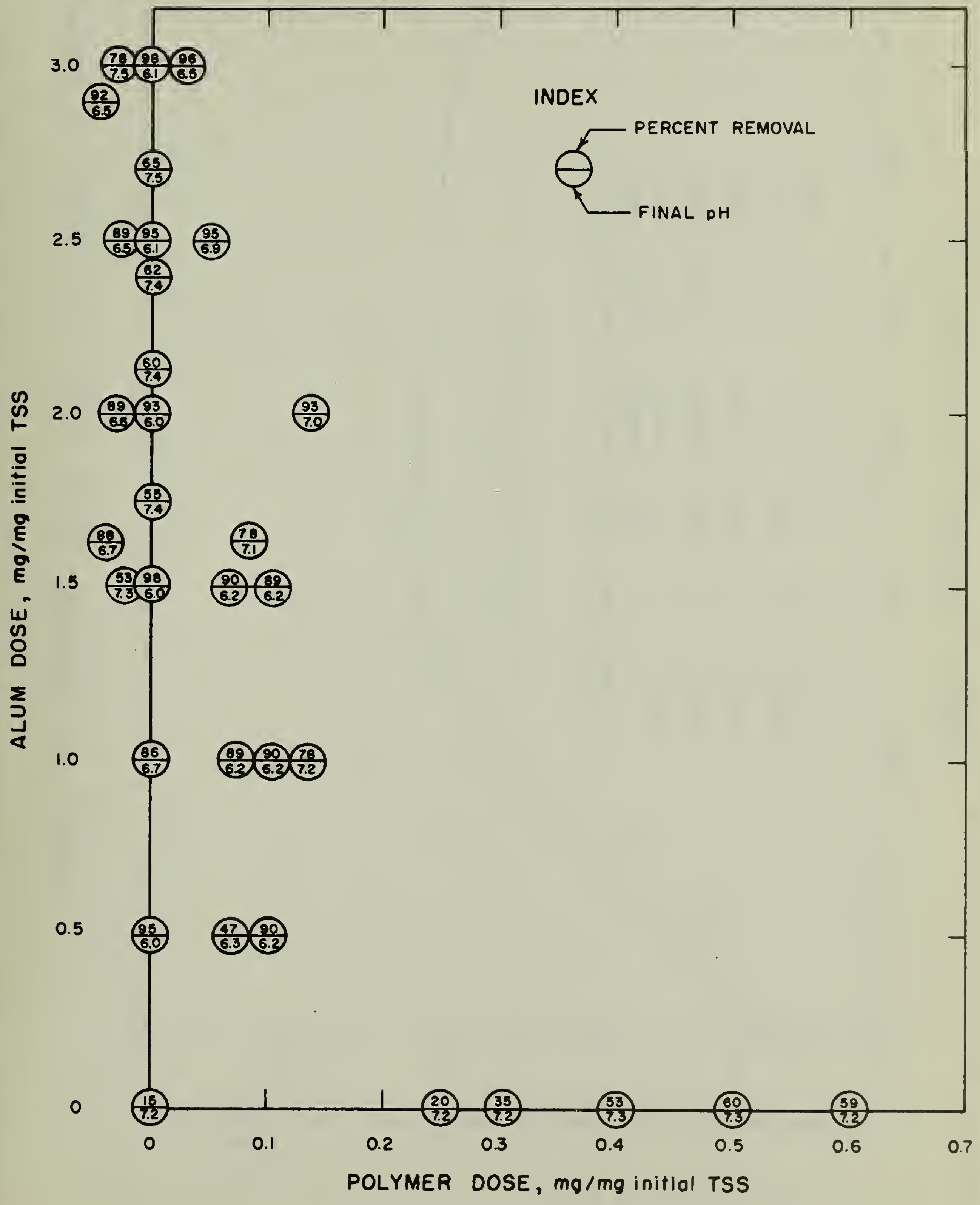
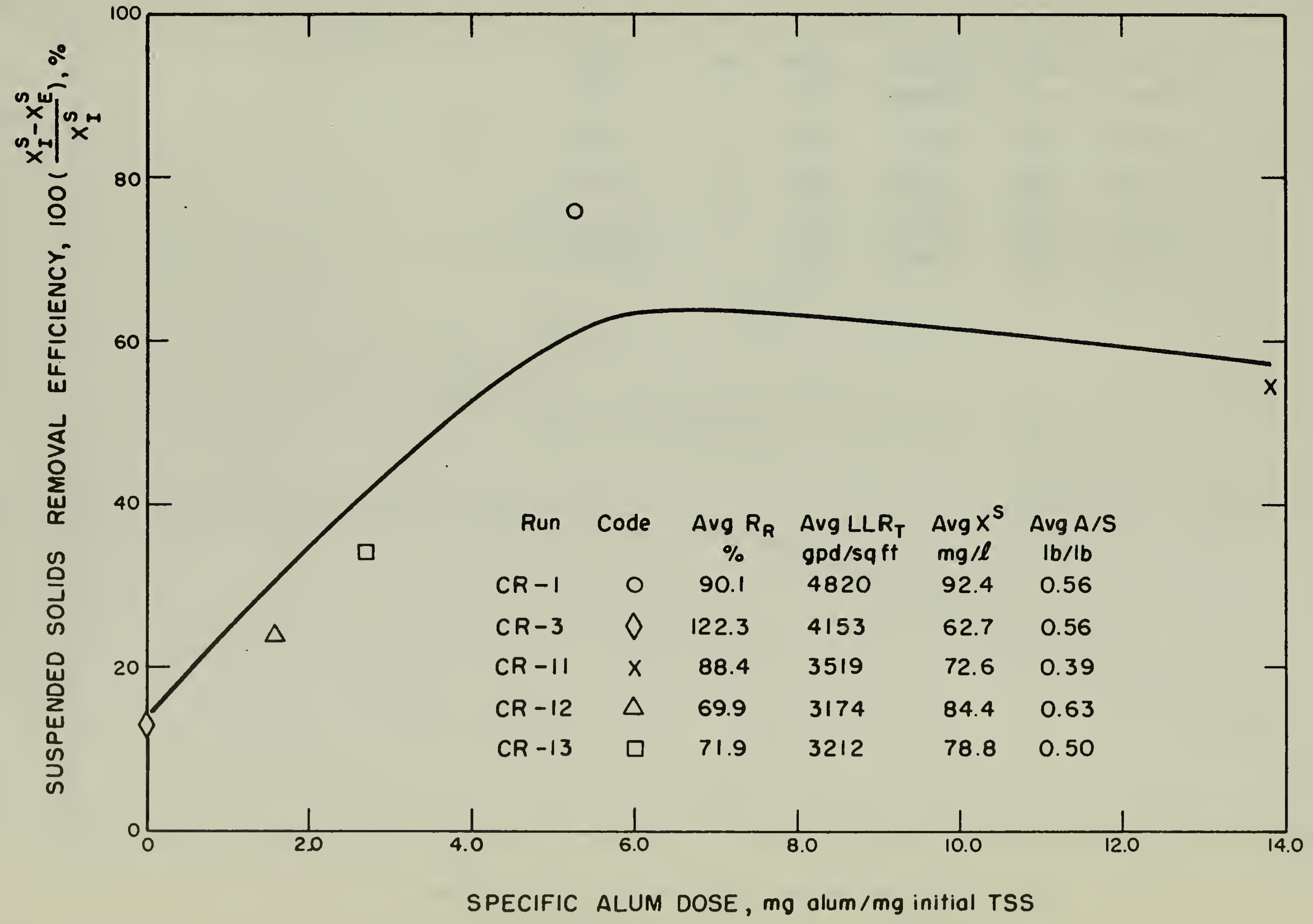


FIGURE IV-2

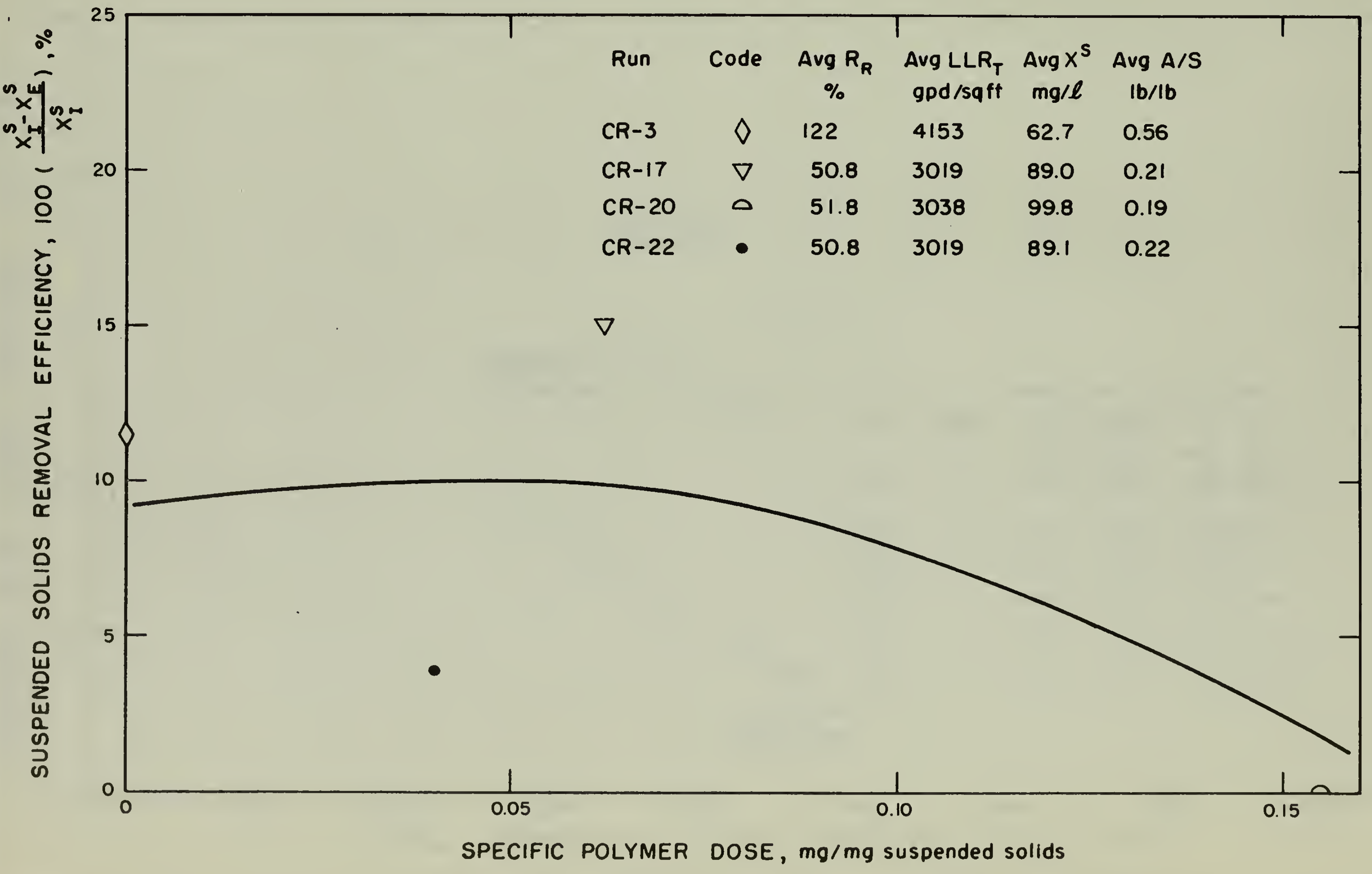
EFFECT OF SPECIFIC ALUM DOSE ON PROCESS EFFICIENCY



Run	Code	Avg R_R %	Avg LLR_T gpd/sq ft	Avg X^S mg/ℓ	Avg A/S lb/lb
CR-1	○	90.1	4820	92.4	0.56
CR-3	◇	122.3	4153	62.7	0.56
CR-11	×	88.4	3519	72.6	0.39
CR-12	△	69.9	3174	84.4	0.63
CR-13	□	71.9	3212	78.8	0.50

FIGURE IV-3

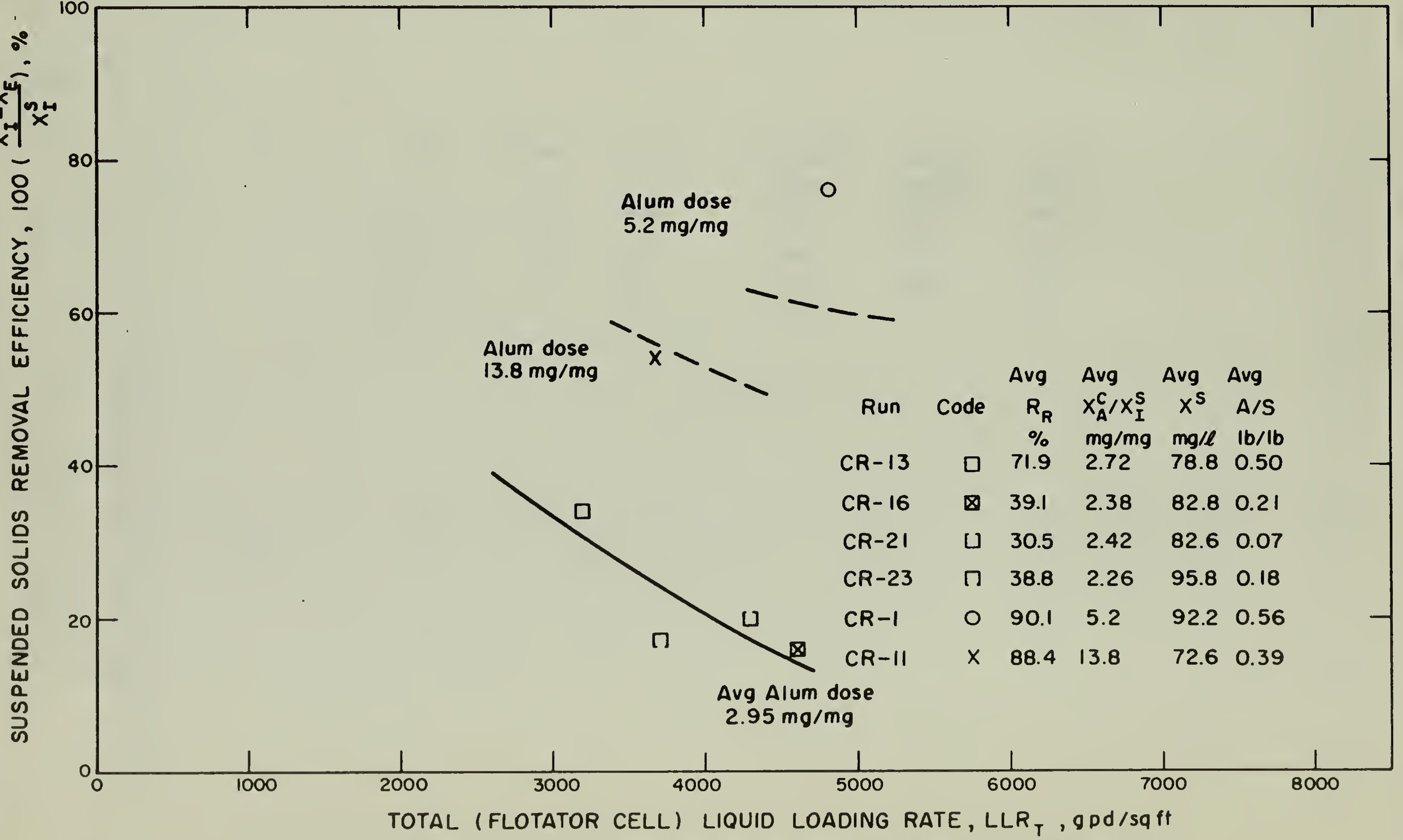
EFFECT OF SPECIFIC POLYMER DOSE ON PROCESS EFFICIENCY



Run	Code	Avg R_R %	Avg LLR_T gpd/sqft	Avg X^S mg/ℓ	Avg A/S lb/lb
CR-3	◇	122	4153	62.7	0.56
CR-17	▽	50.8	3019	89.0	0.21
CR-20	⌓	51.8	3038	99.8	0.19
CR-22	●	50.8	3019	89.1	0.22

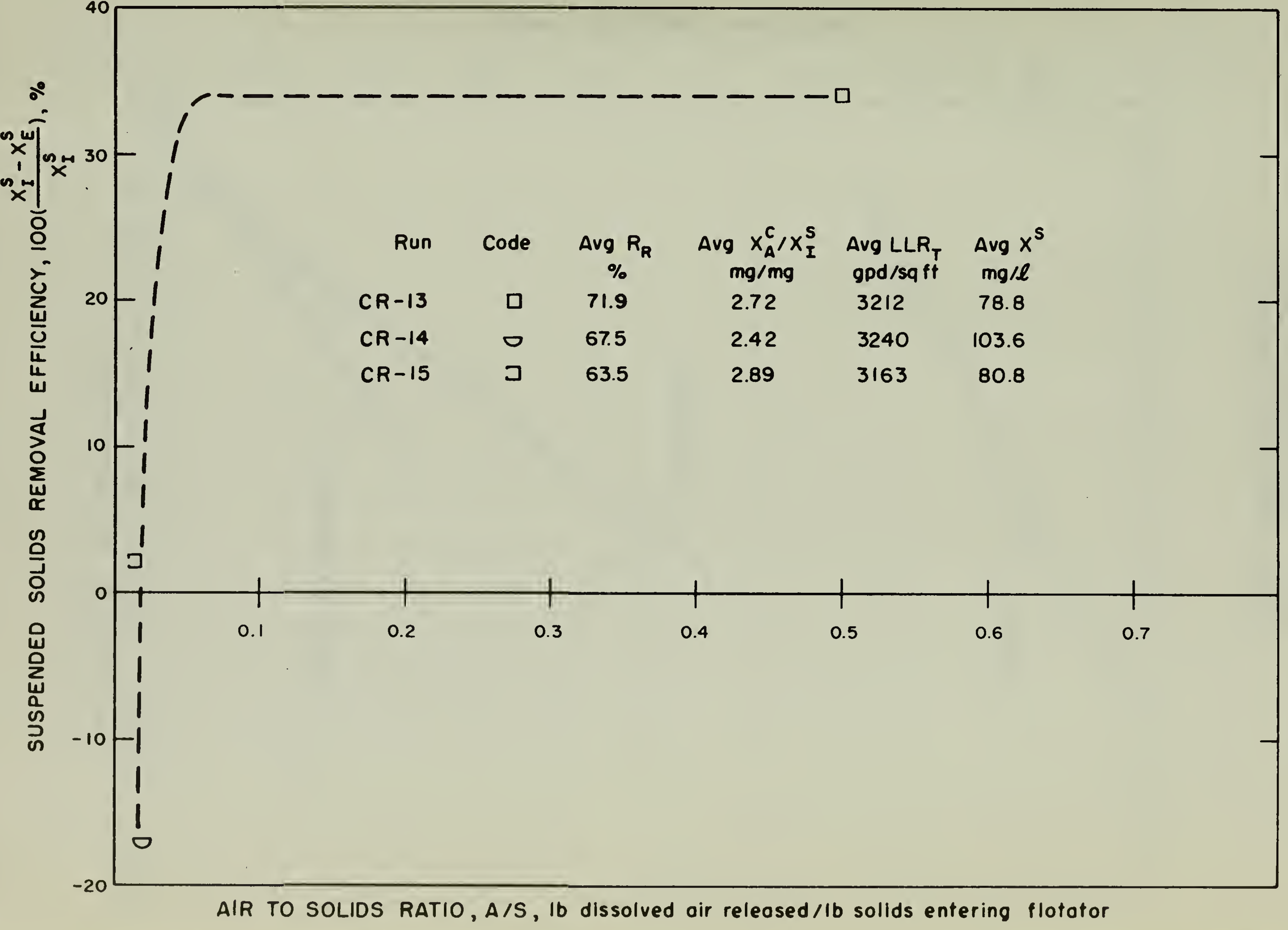
FIGURE IV-4

EFFECT OF TOTAL LIQUID LOADING RATE ON PROCESS EFFICIENCY



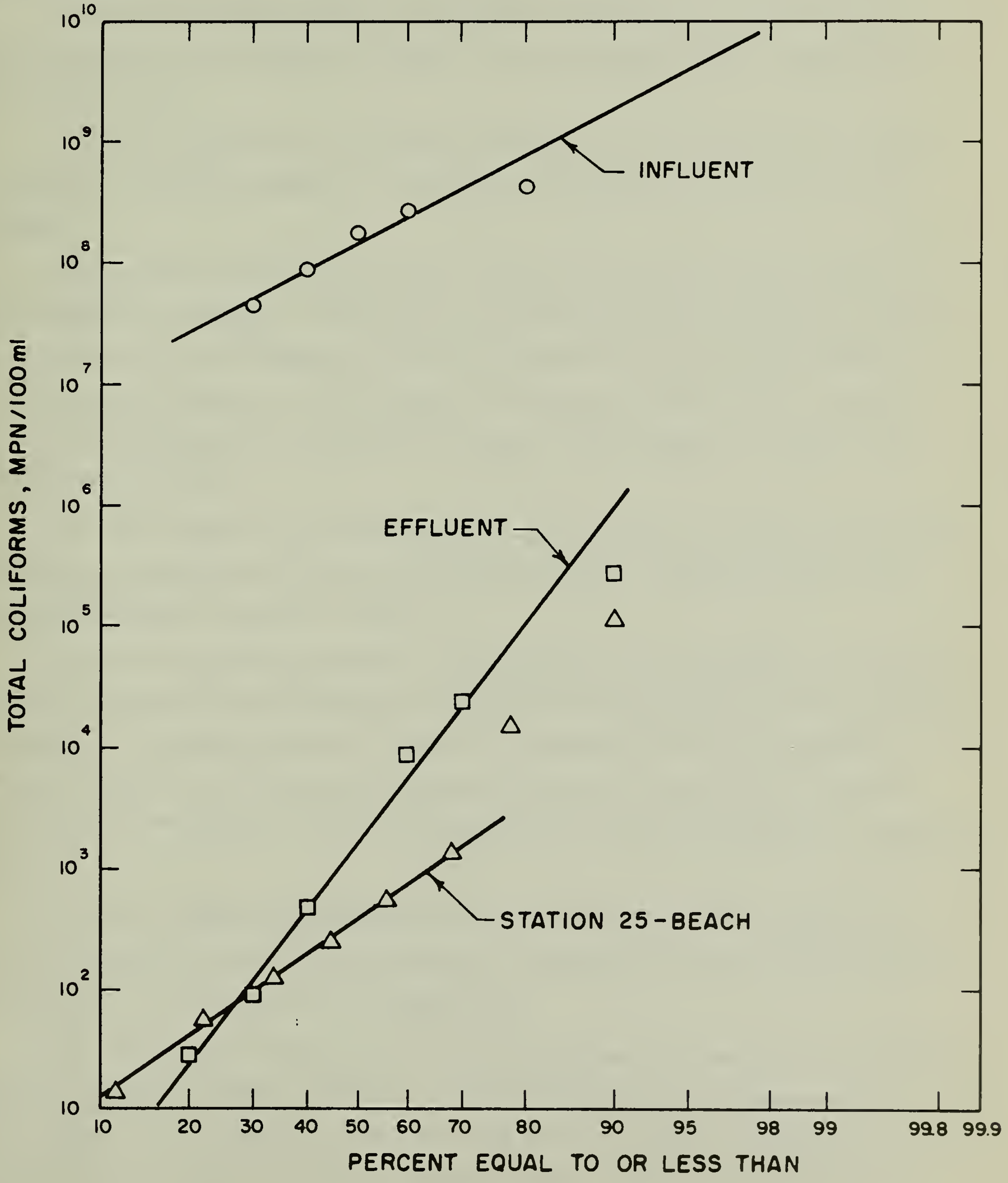
Run	Code	Avg R_R %	Avg X_A^C/X_I^S mg/mg	Avg X^S mg/ℓ	Avg A/S lb/lb
CR-13	□	71.9	2.72	78.8	0.50
CR-16	⊠	39.1	2.38	82.8	0.21
CR-21	⊔	30.5	2.42	82.6	0.07
CR-23	⊓	38.8	2.26	95.8	0.18
CR-1	○	90.1	5.2	92.2	0.56
CR-11	X	88.4	13.8	72.6	0.39

EFFECT OF AIR TO SOLIDS RATIO ON PROCESS EFFICIENCY



Run	Code	Avg R_R %	Avg X_A^C/X_I^S mg/mg	Avg LLR_T gpd/sq ft	Avg X^S mg/ℓ
CR-13	□	71.9	2.72	3212	78.8
CR-14	D	67.5	2.42	3240	103.6
CR-15	⊐	63.5	2.89	3163	80.8

DISTRIBUTION OF OBSERVED MPN VALUES (TOTAL COLIFORM DATA)



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CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions are based on the results and findings of the dry-weather continuous run tests with the Baker Street dissolved air flotation plant:

(1) The dissolved air flotation facility can be operated to effect a maximum turbidity removal in excess of 60 percent from the influent stream.

(2) Maximum observed pollutant removals effected by the dissolved air flotation process, irrespective of operating mode or condition, were 93.5 percent for settleable solids, 63.2 percent for HEM, 100 percent for floatable materials, 53.0 percent for total nitrogen, 99.0 percent for orthophosphate, 95.0 percent for color, 70.5 percent for BOD, and 77.0 percent for COD.

(3) The removal of pollutants at a given level of process variables, and with air/solids ratio nonlimiting, was greatly dependent upon the type and dosage of chemical additive.

(4) Alum was more effective than polymer for the chemical conversion of the influent solids to forms susceptible to separation by dissolved air flotation. It should be noted that the influent solids had undergone the equivalent of primary sedimentation prior to flotation as a result of prolonged retention in the influent works to the dissolved air flotation facility.

(5) With alum pretreatment and an effluent pH in the range of 6.1 to 7.0 process efficiency (as measured by turbidity removal) was found to be maximum at the dosage of 6.0 mg/mg TSS.

(6) Chemical treatment with alum and polymer in combination effected better average pollutant removals of 87.5 percent for orthophosphate, 98.5 percent for floatables, and 25.4 percent for total nitrogen than treatment with alum alone where average removals were 80.3, 97.5, and 22.9 percent respectively.

(7) Increasing process efficiency was observed with increasing alum dosages and with decreasing liquid loading rates.

(8) On the basis of the limited data available, there was no substantial difference in turbidity removals between operation of the dissolved air flotation facility in flotator recycle and influent recycle modes during the dry-weather tests.

(9) The character of the float/solids, which for convenience was combined into a single waste stream for analyses, derived from the dissolved air flotation process was dependent on the type and amount of chemical used for pretreatment. Average pollutant characteristics ranged, depending upon specific chemicals, from 22 to 50 mg/l for HEM, 23 to 26 mg/l for total nitrogen, 13 to 16 mg/l for ammonia nitrogen, 0.02 to 0.27 mg/l for nitrate nitrogen, 0.5 to 1.8 mg/l for orthophosphate and 98 to 584 mg/l for TSS.

RECOMMENDATIONS

Based on the conduct of the dry-weather tests and observations the following recommendations for the Baker Street dissolved air flotation facility are presented:

(1) The Baker Street dissolved air flotation facility should be operated during dry-weather and wet-weather conditions at the following specific chemical doses:

(a) Alum: greater than 4 mg/mg TSS
Caustic: sufficient to maintain near neutral pH

(b) Alum and Polymer Combined: 1 to 2 mg alum with 0.05 to 1 mg polymer/mg TSS

(2) Based on pressure gage tests, the air-lift pumps should be operated at a pressure in the range of 5 to 6 psig.

(3) Although the effect on process performance of intermittent versus continuous operation of the skimmer system was not investigated, the skimmer system appeared to work well during the dry-weather tests. Therefore the skimmer system should continue to be set for continuous operation

of the scum pipe at a front skimming depth of 2 inches, and back skimming depth of 1 inch.

CHAPTER VI

REFERENCES

1. *Characterization and Treatment of Combined Sewer Overflows*, report to City and County of San Francisco, by Engineering-Science, Inc., November 1967.

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3. *Urban Storm Runoff and Combined Sewer Overflow Pollution,* report to the U.S. Department of the Interior, Federal Water Quality Administration, by Aerojet General Corporation, October 1970.

4. *Standard Methods for Examination of Water and Wastewater,* 12th Edition, 1965.

5. *Determination and Removal of Floatable Material from Wastewater,* report by Engineering-Science, Inc. to the U.S. Department of Health, Education, Welfare, U.S. Public Health Service, 1965.

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